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14. ABSTRACT

Mobile electric power (MEP) generation and distribution is a critical and growing need across the full range of military operations. The objective of this study was to analyze future Marine Corps MEP generation and environmental control unit (ECU) capabilities to determine requirements, identify gaps, excesses, and shortfalls and to develop and evaluate alternatives that address these capability gaps, excesses and shortfalls. The Study comprises two phases: Phase I, which is the subject of this report, documents Marine Corps MEP and ECU requirements on a Table of Authorized Materiel Control Number (TAMCN)-by-TAMCN basis, assesses capabilities and identifies excesses, gaps and shortfalls in those MEP and ECU capabilities in the 2012 to 2020 timeframe. Phase II will analyze the capabilities and requirements of a Marine Expeditionary Brigade (MEB) and Marine Expeditionary Unit (MEU) to provide MEP generation and ECU support in a tactical environment.
The Study's scope encompasses all Marine Corps equipment requiring MEP and ECU support that is projected to be operational during the Study's timeframe.

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In Support of the Marine Corps Studies System

Mobile Electric Power and Environmental Control Requirements Study

Final Report

18 December 2009

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Marine Corps Logistics, Modeling and Simulation Services

FINAL REPORT

Mobile Electric Power and Environmental Control Requirements Study

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Abstract

Mobile electric power (MEP) generation and distribution is a critical and growing need across the full range of military operations. The objective of this study was to analyze future Marine Corps MEP generation and environmental control unit (ECU) capabilities to determine requirements, identify gaps, excesses, and shortfalls and to develop and evaluate alternatives that address these capability gaps, excesses and shortfalls. The Study comprises two phases:

- Phase I, which is the subject of this report, documents Marine Corps MEP and ECU requirements on a Table of Authorized Materiel Control Number (TAMCN)-by-TAMCN basis, assesses capabilities and identifies excesses, gaps and shortfalls in those MEP and ECU capabilities in the 2012 to 2020 timeframe.
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EXECUTIVE SUMMARY

ES.1 Objective and Scope

Mobile electric power (MEP) generation and distribution is a critical and growing need across the full range of military operations. The Marine Corps is increasingly fielding many systems that require MEP and environmental control unit (ECU) assets. The objective of this study is to analyze future Marine Corps MEP generation and ECU capabilities to determine requirements, identify gaps, excesses, and shortfalls and to develop and evaluate alternatives that address these capability gaps, excesses, and shortfalls in order to provide a basis for a sound acquisition strategy. The Study comprises two phases:

- Phase I, which is the focus of this report, documents Marine Corps MEP and ECU requirements and capabilities and identifies excesses, gaps, and shortfalls in Marine Corps MEP and ECU capabilities in the timeframe of the study.
- Phase II will analyze the capabilities and requirements of a Marine Expeditionary Brigade (MEB) and Marine Expeditionary Unit (MEU) to provide MEP generation and ECU support in a tactical environment, to analyze excesses, gaps and shortfalls in the tactical environment, and to analyze and recommend alternatives to address the excesses, gaps and shortfalls of MEP generation and ECU assets.

The Study's scope encompasses all Marine Corps equipment requiring MEP and ECU support that is projected to be operational during the 2012 to 2020 timeframe. In order to represent a sample of MEP/ECU employment across the full range of military operations, in Phase II the Study will consider both a MEU conducting amphibious operations as part of a joint campaign and a MEB conducting sustained operations ashore (SOA).

ES.2 Methodology

The Study Team accomplished Phase I through the four tasks described below.

ES.2.1 Task 1 - Determine Requirements

The Study Team determined Marine Corps MEP and ECU loads for the 2012 to 2020 timeframe using a variety of sources, including technical manuals (TM), previous studies, results of the recent MEP survey, and interviews with subject matter experts (SME).

The Study Team used a bottom up approach for MEP requirements and examined all MEP-consuming equipment (loads) projected to be operational in a Marine Expeditionary Force (MEF) in the 2012 to 2020 timeframe. Loads were classified as critical, required, or important and their support classified as dedicated, exclusive, or grid[1]. By integrating these data with tables of organization and equipment (TO/E) extracted from the Total Force Structure Management System (TFSMS), the Study Team tabulated unit-by-unit MEP requirements through the Future Years Defense Plan (FYDP). Projection beyond 2015 was based on acquisition plans for future programs of

[1] These load categories are defined and discussed in Chapter 2.

record (POR). The Study Team also examined projected ECU requirements in the 2012 to 2020 timeframe and collected ECU data including Table of Authorized Materiel Control Number (TAMCNs) of items requiring ECU support, amount of cooling/heating required, and TFSMS Approved Acquisition Objective (AAO) quantity by unit. All MEP and ECU loads, and the sources thereof, were collected in a MEP database together with TO/E data from TFSMS.

ES.2.2 Task 2 - Determine Capabilities

The Study Team determined programmed Marine Corps MEP and ECU capabilities for the 2012 to 2020 timeframe using a bottom up approach similar to Task 1. Data was collected on all programmed MEP and ECU equipment. This data was integrated into the MEP database developed in Task 1. The Study Team also assessed the possible impact of exporting power from the Joint Light Tactical Vehicle (JLTV).

ES.2.3 Task 3 - Excess/Gap/Shortfall Analysis

Based on the estimates developed in Tasks 1 and 2, the Study Team analyzed excesses, gaps, and shortfalls in the MEF's capability to support the MEP and ECU loads in the 2012 to 2020 timeframe. Excesses, gaps, and shortfalls were tabulated by MEP support category (dedicated, exclusive, or grid).

ES.2.4 Task 4 – Other Issues

The Study Team examined emerging environmental regulations and restrictions (domestic and allied nations) that apply to refrigerants in ECUs. The Study Team also examined MEP assets procured by the US Navy (blue dollars in support of green), for the Marine Air Wing, in order to identify any commonalities between those assets and Marine Corps procured MEP assets.

ES.3 MEP and ECU Analysis

ES.3.1 Data Requirements

The Study Team employed the TFSMS to identify principal end items (PEI), by TAMCN, assigned to operational forces, either currently or in 2015 (FYDP). These systems were reviewed to determine which TAMCNs could potentially consume electrical power or require ECU support. The Study Team conducted a document search for systems requiring power or ECUs, including government furnished information (GFI), the technical publications repository at Marine Corps Logistics Base (MCLB) Albany, and, to a lesser extent, publically available information on the web. For TAMCNs requiring ECU support, the Study Team identified the appropriate ECU(s) by TAMCN based upon the British thermal unit per hour (BTU/hr) required and the most current ECU providing that capability.

By far the most significant data issue is missing documentation. Other issues Included old documentation, contradictory data from multiple sources and multiple equipment models, nonstandard battery chargers, multiple power input options, and unknown duty cycles.

The Study Team mitigated some of these data issues by estimating the electrical power requirements for a number of systems. Table ES-1 provides a summary of the data collection effort.

Table ES-1 Load Data Collection Status

	Number of TAMCNs
Total Researched	**771**
Missing or Uncertain Data	**279**
Determined to Not Require MEP	**181**
Documented MEP Load	**186**
Documented Dedicated Support	**25**
Documented Exclusive Support	**33**
Documented ECU Requirement	**51**
Analogous MEP/ECU Requirement	**125**

Key study assumptions are described in Chapter 3.1. Among these are

- Command and Control (C2) systems are critical loads.
- Systems assigned to the Medical Battalions are critical loads.
- Water purification and refrigeration are required loads.
- The effects of all battery operated and direct current (DC) systems on MEP requirements can be accounted through battery chargers and power adapters.
- Duty cycle (a significant unknown for most important systems) was treated as a worst case of 100%.
- Critical loads outside the Air Combat Element (ACE) require 100% backup and that other loads have no backup[2].

ES.3.2 Load Estimates

Using the collected system power consumption data and the TO/E from TFSMS (AAO from 5 June 2009), the loads and generating capacity of each were tabulated. To mitigate the impact of missing data, loads for collections of items employed in tents and shelters were estimated using planning factors from the Basic Communications Officer Course (BCOC) and FM 5-424, *Theater of Operations Electrical Systems*. To employ these estimates, the Study Team identified the set of TAMCNs expected to be used in these tent/shelters and the ECUs typically associated with them.

Future MEP requirements depend on a number of factors including: new POR, broad based technical trends, and Marine Corps policy and priorities affecting use of equipment, especially ECUs. The Study Team retrieved projects from The Online Project Information Center (TOPIC) and estimated power consumption for future systems.

Additional programs or trends that were assessed for future MEP requirements included deployment of the JLTV, trends in ECU efficiency/power requirements, trends in efficiency improvements of computers, the proliferation of personal communications and electronic systems, improved insulation for general purpose (GP) tents which drive ECU

[2] ACE requirements, including backup, were provided by SME.

demand, and renewable energy sources that may augment traditional generators. Discussions with SMEs indicated that most technology improvements would be applied to increased operational performance rather than reduced MEP demand.

ES.3.3 Shortfall Analysis

As a surrogate for a specific geographic laydown, the Study Team used company level AAOs, with MEP demand categorized by classification and support, as defining “load centers” that must be separately supported. The Study Team subdivided large load centers, using the unit’s mission statement, when it was apparent the company level AAO would not be employed at a single load center.

The Study Team coded an algorithm that assigned the largest possible generator to a load center, using the assumptions that loads are between 50% and 65% or between 60% and 80% of rated generator power. The Study Team analyzed several cases:

- 2012 Documented Loads: the Study Team estimated the number of each type of generator required to support the load centers using power requirements defined using the TFSMS TO/E. ECU requirements were defined to be those in the TFSMS TO/E.
- 2012 Planning Factor Loads: the Study Team estimated the number of each type of generator required to support the tent/shelter-based estimated load centers. ECU requirements were based on ECUs assigned to each tent/shelter and each system requiring an ECU, based on available documentation.
- 2020 Loads were estimated using planning factors and included future POR.

The shortfall results, a comparison of total requirements in the Fleet Marine Force (FMF) to the AAO, for the three cases described above, are summarized in Figure ES-1. The potential JLTV impact is between 480 and 714 generators depending on the amount of exportable power.

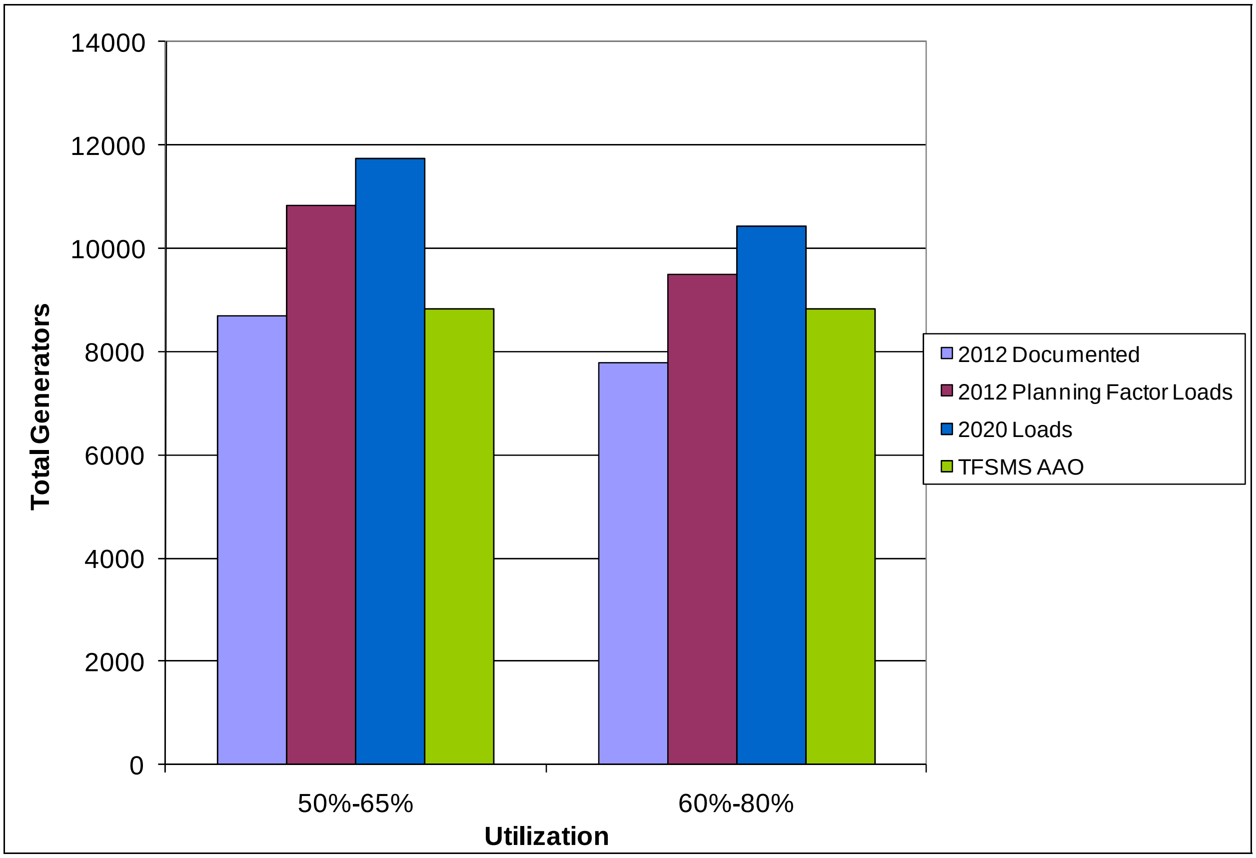

Figure ES- 1 Comparison of FMF Generator Requirements to the AAO

ES.3.4 Gap Analysis

The Marine Corps currently deploys eight standard generator sizes[3]. Given the current suite of standard generators, the existing load centers frequently require more than one generator. Multiple generators supporting a single load center increase the maintenance burden and the complexity of power distribution. In order to reduce the need for multiple generators to support single load centers, the Marine Corps could acquire a new size of generator. The optimum new generator size depends on the distribution of load center sizes. The Study Team addressed this question by postulating a series of possible new sizes, applying the same generator sizing algorithm used in the shortfall analysis, and comparing generator totals. The process was repeated for each candidate generator size, one at a time.

By adding 5 kW generators to the set of standard sizes, the Marine Corps could reduce the total generator requirement by approximately 180 generators in both 2012 and 2020 compared to the baseline cases. The addition of 150 kW generators to the standard set could save approximately 140 generators in both time frames.

ES.3.5 ECU Requirements

As previously stated, ECU requirements were based on assigning ECUs to each tent/shelter and each system requiring an ECU, based on available documentation. Analysis showed a large shortfall of approximately 5000 60k BTU/hr units, caused by

[3] Some end items have component generators of a unique size. Only the standard non-component generators are part of the gap analysis.

the Modular Command Post System, and approximately 10,000120k BTU/hr units caused by the Modular General Purpose Tent System (MGPTS).

ES.4 Environmental Considerations

ECUs are subject to strict and evolving regulations in the US and Europe regarding the working fluid, or refrigerant, used in the system. All current ECUs in the Marine Corps use the R-22 refrigerant, which must be replaced in the coming years. The prime long term candidate for replacing R-22 is R-410A. However, old systems cannot be retrofitted to use R-410A. New equipment can be designed for a wider choice of refrigerants and are expected to perform with higher overall system efficiency.

ES.5 Conclusions

The analysis showed a shortfall of up to 2900 generators and approximately 15,000 ECUs. The shortfall is concentrated in 200 kW generators, partially offset by an excess of some of the smaller generators. These results are driven by the assumption that each tent and shelter will be supplied with an ECU, as is the practice in current deployments. The Marine Corps may or may not adopt this practice as permanent doctrine. Acquiring 5 kW or 150 kW generators could also save approximately 180 or 140 generators respectively.

1. INTRODUCTION

1.1. Background

Mobile electric power (MEP) generation and distribution is a critical and growing need across the full range of military operations. MEP systems need to be lightweight, quickly emplaced, and fuel efficient. They provide a distribution network to operate or support critical command and control (C2) equipment, life support/medical facilities, hygiene equipment, food services, airfields/airbases, artillery and counter-battery fires, and force protection measures.

The Marine Corps is increasingly fielding many systems that require MEP assets. The introduction of C2 systems down to the battalion and company levels and a significant increase in environmental control units (ECUs) are just two examples of electrical power consuming equipment that are putting an increased demand on MEP assets. Exacerbating the situation is the fact that the future requirements for ECUs are ill defined and not well documented.

With limited resources to procure MEP equipment each year, it is imperative that MEP generation capabilities are efficiently matched to electrical power requirements. Identifying future Marine Corps power requirements and capabilities to determine trends, gaps, and excesses in MEP generation will provide program managers with critical insight in developing future MEP acquisition strategies. An implied sub-product of this study will be a defined and documented ECU requirement.

1.2. Objective and Scope

The objective of this study is to analyze future Marine Corps MEP generation and ECU capabilities to determine requirements, identify gaps, excesses, and shortfalls and to develop and evaluate alternatives that address these capability gaps, excesses, and shortfalls in order to provide a basis for a sound acquisition strategy. The Study comprises two phases:

- Phase I documented Marine Corps MEP and ECU requirements and capabilities and identifying excesses, gaps and shortfalls in Marine Corps MEP and ECU capabilities in the timeframe of the study.
- Phase II will analyze the capabilities and requirements of a Marine Expeditionary Brigade (MEB) and Marine Expeditionary Unit (MEU)to provide MEP generation and ECU support in a tactical environment, to analyze excesses, gaps and shortfalls in the tactical environment, and to analyze and recommend alternatives to address the excesses, gaps and shortfalls of MEP generation and ECU assets.

The Study’s scope encompasses all Marine Corps equipment requiring MEP and ECU support that is projected to be operational during the 2012 to 2020 timeframe. In order to represent a sample of MEP/ECU employment across the full range of military operations, in Phase II the Study will consider both a MEU conducting amphibious operations as part of a joint campaign and a MEB conducting sustained operations ashore (SOA).

1.3. Assumptions and Major Factors for Consideration

The Northrop Grumman Study Team (Study Team) assumes the following:

- The Marine Corps will continue to task organize and be employed in Marine Air-Ground Task Forces (MAGTFs).
- The current programs of record (POR) for equipment requiring MEP/ECU support will be executed as planned.

Major factors being considered by the Study Team include:

- There are numerous previous studies, recent lessons learned, and ongoing efforts examining the employment of MEP assets within the Marine Corps.
- Emerging concepts of operations may affect MEP/ECU requirements.
- Future POR, such as the Joint Light Tactical Vehicle (JLTV), will provide exportable power, but Marine Corps acquisition plans and doctrine for use of exportable power are unsettled.
- Navy procured MEP and ECUs may be common to the Marine Air Wings.
- The requirement for ECUs is expanding and undocumented.
- Emerging environmental regulations and restrictions will affect the acquisition of MEP assets and ECUs forthcoming in POM-12.

1.4. Study Approach

The Study will be performed in two phases. In Phase I, the Study Team documented required MEP and ECU loads using a variety of sources, including technical manuals (TM), previous studies, results of the recent MEP survey, and interviews with subject matter experts (SMEs). These loads were classified as critical, required, or important and their support classified as dedicated, exclusive, or grid[4]. By integrating these data with tables of organization and equipment (TO/E) extracted from the Total Force Structure Management System (TFSMS), the Study was able to tabulate unit-by-unit MEP and ECU loads through the Future Years Defense Plan (FYDP). The FYDP currently covers years through 2015. Projection beyond 2015 was based on acquisition plans for future POR. The available/programmed MEP and ECU support was tabulated in the same way. In performing a shortfall/gap analysis, the Study Team considered the concept of employment for supported equipment and standard procedures of utilities SME, such as back-up ratios. Phase II of the Study will apply the requirements and capabilities developed in Phase I to a MEB conducting SOA and to a MEU. Phase I was accomplished through the four tasks described below.

1.4.1. Task 1 - Determine Requirements

The Study Team determined Marine Corps MEP and ECU loads for the 2012 to 2020 timeframe using the results of an initial data collection effort performed by the Government as well as other sources such as: previous MEP studies, TFSMS, technical manuals, and data requests to Product Group representatives at Marine Corps Systems Command and SMEs within the Marine Corps and the U.S. Navy.

[4] These load categories are defined and discussed in Chapter 2.

1.4.1.1. MEP Requirements

The Study Team took a bottom up approach, examining all MEP-consuming equipment projected to be operational in a Marine Expeditionary Force (MEF) in the 2012 to 2020 timeframe. Data collected included, but was not limited to, Table of Authorized Materiel Control Number (TAMCN), nomenclature, technical details of the required power, TFSMS Approved Acquisition Objective (AAO) quantity by unit (TO/E), classification of power required (critical, required, or important), and the type of distribution required (dedicated, exclusive, or grid).

1.4.1.2. ECU Requirements

The Study Team also examined projected ECU requirements in the 2012 to 2020 timeframe. The data collected included TAMCNs of items requiring ECU support, nomenclature, amount of cooling/heating required, and TFSMS AAO quantity by unit (TO/E). Because the ECU acquisition requirement is currently expanding and a projected requirement is not documented, this requirement is especially dependent on SME input and assumptions. All MEP and ECU loads, and the sources thereof, were collected in a MEP database together with TO/E data from TFSMS. To accommodate a range of assumptions or SME opinion, the Study Team prepared high and low estimates.

1.4.2. Task 2 - Determine Capabilities

The Study Team determined programmed Marine Corps MEP and ECU capabilities for the 2012 to 2020 timeframe using a bottom up approach similar to Task 1. Data was collected on all programmed MEP and ECU equipment similar to that being collected for loads. This data was integrated into the MEP database developed in Task 1. As mentioned in the Major Factors for Consideration, there is at least one POR, the JLTV, with significant potential impact on MEP capabilities and requirements whose concept of employment is still evolving. The Study Team developed multiple capabilities projections for the 2012 to 2020 time frame using different assumptions regarding future POR. The assumptions were provided by the Study Team to the Government for review and several adjustments were made in response to government comments. The MEP database was provided to the Government at the conclusion of the Study.

1.4.3. Task 3 - Excess/Gap/Shortfall Analysis

The Study Team analyzed excesses, gaps, and shortfalls in the MEF’s capability to support the MEP and ECU loads in the 2012 to 2020 timeframe. Excesses, gaps, and shortfalls were tabulated by MEP support category (dedicated, exclusive, or grid). Exclusive power excesses and gaps were further subdivided by characteristic (400 Hz, high voltage, etc.). The Study Team used the MEP database, which includes TO/E data as of June 2009, to generate a unit-by-unit shortfall analysis.

1.4.4. Task 4 – Other Issues

The Study Team examined emerging environmental regulations and restrictions (domestic and allied nations) that apply to refrigerants in ECUs. A preliminary discussion of their impact on the future acquisition strategy of MEP assets and ECUs is contained in Chapter 4.

The Study Team also received data on MEP assets procured by the US Navy (blue dollars in support of green), for the Marine Air Wing, in order to identify and discuss commonalities between those assets and Marine Corps procured MEP assets.

1.5. Organization of the Document

This Final Report documents the results of all four tasks described above. Chapter 2 describes the data collection and organization effort, including data sources, issues encountered, and document search status. Chapter 3 describes the shortfall and gap analysis including assumptions, methodology, and results. Chapter 4 describes environmental regulations and their impact on future capabilities. Appendices are provided for a bibliography, acronym list, MEP loads by TAMCN, and other important data.

2. DATA COLLECTION AND ORGANIZATION

The Study's scope encompasses the entire Marine Corps operating forces and, therefore, every piece of equipment that requires electric power or cooling. The required support for this equipment depends on both its technical characteristics and concepts of employment, necessitating an extensive data collection effort. This chapter discusses the data relevant to the Study, the methods used and issues encountered in collecting them, and their organization in a Mobile Electric Power database (MEPDB).

2.1. Data Requirements

2.1.1. Load Categories

As stated above, the MEP requirements for a set of electrical/cooling loads depend on both their technical characteristics and concepts of employment. These factors are categorized by a classification of the importance of the function supported and a description of the distribution architecture as follows.

Power is classified as:

- **Critical Power** - needed 24 hours per day and loss of power is life threatening;
- **Required Power** - extended loss of power will become life threatening or can cause large economic losses; or
- **Important Power** - not tactical and loss is nonlife threatening.

Power support is categorized as:

- **Dedicated** – a generator supports a single end item;
- **Exclusive** – the power requirements have unusual technical characteristics (described below); or
- **Grid** – multiple functions/systems are supported by a distribution grid and one or more generators.

Power classification and support are independent factors, so that nine combinations exist. Power classification is derived from the function performed or mission supported by the equipment. For example, lighting in a billeting tent/shelter may be classified important, but in a medical facility, lighting could be critical. Power classification was used to determine backup requirements. The Study's assumptions on the criteria for power classification and its treatment are addressed in the analysis of shortfalls in Chapter 3.

Equipment technical characteristics determine exclusivity. Alternating current (AC) is produced in a variety of voltages, frequencies, and phase relationships. Standard US residential power is 110 or 220 volts AC (VAC) at 60 Hertz (Hz), one or three phases. Voltages up to 380 VAC and frequencies of 50 or 60 Hz are not considered exclusive requirements. The three phases can be connected at the generator in either a delta or "Y" (Wye) configuration[5]. Most circuits are configured as delta. Equipment that requires 400 Hz, Wye phasing, or greater than 400 volts, is classified as exclusive.

[5] The effect of losing one of the phases is different in the two configurations.

2.1.2. Data Elements

The Study Team attempted to collect all data relevant to identifying the amount of electrical power and cooling required by each principal end item (PEI) and to assigning the requirement to one of the nine categories of class and support. The Study Team also collected associated data, such as fuel consumption, that may be useful to further analysis. The specific data elements for MEP, ECUs, and other loads differ somewhat. Table 2.1-1 lists the data elements which the Study Team attempted to collect for each type of PEI.

Table 2.1-1 Data Elements

Data Element	Description	MEP	ECU	Load
TAMCN	Table of Authorized Materiel Control Number (TFSMS)	x	x	x
Name	Item nomenclature (TFSMS)	x	x	x
Model	Item model number (TFSMS)	x	x	x
NSN	National stock number (TFSMS)	x	x	x
ID Code	Item designator code (TFSMS)	x	x	x
Embedded Gen	Model number or capacity of embedded generator, if any			x
Dedicated Gen	Model number or capacity of dedicated generator, if any			x
Exclusive	Requirement for exclusive power (e.g., 400Hz, Wye) if any		x	x
Max power	Maximum power rating or consumption	x	x	x
kW or KVA	The units specified for max power (kW or KVA)	x	x	x
PF	Power factor	x	x	x
Voltages	Operating voltage(s)	x	x	x
Amps	Operating amperage(s)		x	x
HZ	Operating frequency (e.g., 60Hz)	x	x	x
Phase (1 or 3)	Operating Power phases	x	x	x
# wires	Number of power connection leads (2, 3, 4, 5)	x	x	x
Phase geometry	For three-phase generators and loads, Wye or Delta	x	x	x
Duty Cycle	Percentage of time a load draws power			x
Classification	Power classification (critical, required, or important)			x
Support	Power support designation (dedicated, exclusive, grid)			x
Embedded ECU	Model number or capacity of embedded ECUs, if any			x
ECU (BTU/hr)	The cooling capacity or cooling requirement in BTU/hr per hour		x	x
ECU (H/V)	Whether the ECU orientation is horizontal or vertical		x	x

2.2. Data Collection

2.2.1. Methodology and Sources

The Study Team employed the TFSMS to identify PEI, by TAMCN, assigned to operational forces, either currently or in 2015 (FYDP). These systems were reviewed (by examining the system's name) to determine which TAMCNs could potentially consume electrical power or require ECU support. If there was any doubt whether a PEI might require MEP/ECU support, it was retained for further review.

A TAMCN was determined to be assigned to operational forces if TFSMS showed an approved acquisition objective (AAO) quantity greater than zero for that TAMCN in any operational unit(s). While TFSMS provides data fields for tracking multiple categories of equipment allocation (e.g., authorized quantity, planned quantity, unfunded quantity, and net asset posture [formerly "on-hand"]), the Study Team used the AAO quantity because it represents the baseline required quantity of each TAMCN in each unit. The Study Team used TFSMS data extracted in December 2008 to identify these TAMCNs of interest. Because TFSMS data is fluid in nature, the Study Team also looked at TFSMS data in February and March 2009 in order to add or remove TAMCNs of interest as appropriate. For example, the Common #22 Tool Set, TAMCN C79052B, is a relatively new item, which had an AAO of one (1) in the supporting establishment in the earlier TFSMS data, but had an updated AAO of more than 300 across Marine Corps operational units in the latest TFSMS data. (If analysis had been completed for a TAMCN that was subsequently removed from the operation forces in TFSMS, data for that TAMCN was retained.)

Once the candidate list of TAMCNs was developed, the Study Team conducted a document search. The search domain included government furnished information (GFI) provided by the Study Sponsor, the technical publications repository at Marine Corps Logistics Base (MCLB) Albany, and, to a lesser extent, publically available information on the web. The Albany publications repository was searched by TAMCN, Item Designator (ID) number, and key word resulting in a large collection of technical manuals (TM), parts lists (SL-3), fielding plans (FP), and User's Logistics Support Summaries (ULSS), each document being associated with one or more TAMCNs. All these documents were reviewed to find and extract the data elements listed in Table 2.1-1. For TAMCNs requiring ECU support, the Study Team also identified the appropriate ECU(s) by TAMCN based upon the BTU/hr required and the most current ECU providing that capability, per Program Manager Expeditionary Power Systems (PM EPS) documentation.

2.2.2. Data Issues

Most of the official documents follow a prescribed format so that locating the electrical and ECU data contained therein was usually straightforward. However, for a number of TAMCNs, including a large number of tools and test, measurement, and diagnostic equipment (TMDE), the TM comprised the commercial user's manual in the manufacturer's format. For many TAMCNs, the only document found was the SL-3 and MEP/ECU requirements had to be inferred from the parts themselves. For example, the largest electrical load in the Intermediate Level Electricians Tool Kit, B79002B, appears to be a 500 watt (W) floodlight that is not mentioned in the system description section of the SL-3.

By far the most significant data issue is missing documentation. No documentation on power consumption could be found for a large number of TAMCNs of interest. There were several other recurring issues.

- **Old documentation**: some of the documentation is decades old. In many cases, the system described is obviously obsolete, but there were also cases where the old document is the only source and its relevance was unclear.
- **Contradictory data**: multiple sources sometimes gave different values for the same parameter. For example, the Tactical Exploitation Group – Main, A08797G, is listed as requiring either 10kW or 50kW of MEP depending on the source. In this case, the 50kW figure came from the ULSS and was broken down by component. The more detailed source was chosen.
- **Multiple models**: for other TAMCNs, the contradictions arose from the existence of multiple models. The most striking example of model differences was the Shop Equipment, Tire, C79017B. Model MCSET-30 has a component generator and two 18,000 BTU/hr ECUs; model MCSET-40 has a component 60,000 BTU/hr ECU, but no generator; and model MCSET-41 had no available documentation. It is important to note that TFSMS allocates equipment to units by TAMCN only, and does not account for the specific model numbers that may be associated with that TAMCN. TFSMS identified the model MCSET-41 as the "current preferred variant" for the TAMCN C79012B, but only shows unit quantities by TAMCN and does not identify which of these three models have been acquired by the various units that require them.
- **Battery chargers**: many TAMCNs, in particular many tools and TMDE, include battery operated components with non-standard adapters or chargers.
- **Computer systems**: ULSS 002899-15, "Marine Corps Common Hardware Suite [MCHS] Modernization Project – FY 01," lists nominal power consumption information for TAMCNs covering laptops, workstations, and servers in the MCHS. The issue is that computer hardware is frequently refreshed and commercial venders are placing greater emphasis on energy efficiency. There are also 25 TAMCNs that comprise computers of some sort, with mission specific applications, for which no documentation could be found. The Study Team applied the ULSS 002899-15 values to all these systems.
- **Multiple inputs**: many systems can operate on battery or direct current (DC) from a vehicle, but also can accept AC power. An example is the Charger, Battery, Universal, Portable, H77202B, which can operate on 24VDC or 110 VAC. These systems were assumed to operate on AC.
- **Duty cycle**: most systems are not run continuously. Grid support need only provide power equal to the average requirement (plus some margin to prevent temporary demand spikes from tripping circuit breakers). The Study assumed 100% duty cycle.

The Study Team mitigated some of these data issues by estimating the electrical power requirements for a number of systems. The Study Sponsor provided a list of TAMCNs that can be considered representative of kits and sets. The Study Team identified all components requiring power and investigated each item, by part number, using publicly available sources. Where the specific part could not be found, a similar part was substituted. Once the representative parts were researched, the Study Team reviewed available SL-3s for the other TAMCNs with ambiguous or incomplete data and associated representative parts with analogous components of the TAMCN in question.

2.2.3. Status

The complete set of collected load data is contained in Appendix C. Table 2.2-1 provides a summary of the data collection effort. Even after estimating loads where possible, there remained 279 TAMCNs with incomplete data. To mitigate the impact of these remaining missing data, the Study Team used planning factors for consumption of tents and shelters, as described in section 3.2.2. After determining which TAMCNs would typically be used in a tent/shelter, 35 of these 279 TAMCNs are assigned to units with MEP requirements and are still unaccounted for; MEP/ECU requirements could be higher due to this residual uncertainty.

Table 2.2-1 Load Data Collection Status

	Number of TAMCNs
Total Researched	**771**
Missing or Uncertain Data	**279**
Determined to Not Require MEP	**181**
Documented MEP Load	**186**
Documented Dedicated Support	**25**
Documented Exclusive Support	**33**
Documented ECU Requirement	**51**
Estimated MEP/ECU Requirement	**125**

3. SHORTFALL AND GAP ANALYSIS

3.1. Analytic Assumptions

The Study Team devised a number of rules or assumptions to account for the wide variety of system types and data sources in a consistent fashion and to form the basis of alternate scenarios of support requirements.

3.1.1. Load Assumptions

In identifying MEP loads and categories, the Study Team assumed:

1. Where generators are a component of a PEI, that PEI requires dedicated support and the component generator is properly sized.
2. Where generators are identified by model or TAMCN as using unit responsibility items (UURI), or similarly described as direct support for a PEI, that PEI is assumed to require dedicated MEP support. However, unless the identified generator was the only information available on power requirements, its size was subject to change. Conversely, if MEP support is neither in the form of a component generator, specifically stated as dedicated, nor identified as a specific system, it is not dedicated.
3. A PEI requires exclusive power only if it cannot be operated without power having some exclusive requirement (400 Hz, Wye, or greater than 400 VAC).
4. Command and Control (C2) systems are critical loads. The Study classifies all A-TAMCNs except tools and TMDE as C2 systems.
5. All systems assigned to the Medical Battalions are critical loads.
6. Water purification and refrigeration are required loads.
7. The effects of all battery operated and DC systems on MEP requirements can be accounted through battery chargers and power adapters.

As stated in Section 2.2, duty cycle is a significant unknown for most systems. Critical and Required systems by definition have a 100% duty cycle. The Study uses a worst case of 100% for all important systems. While this level of use may be close to accurate for systems such as lights and battery chargers, it may overstate requirements for many systems. SME input on more reasonable assumptions for most equipment should inform Phase 2 of the Study.

3.1.2. Generator Assumptions

Once loads were estimated, two additional assumptions were used in calculating the portfolio of required generators: backup ratios and capacity factors. The Study Team assumed that critical loads outside the Air Combat Element (ACE) require 100% backup and that other loads have no backup. SME from the ACE provided an explicit count of backup generator requirements that are given in Appendix G.

Generators are typically not run at full rated load due to overheating. They are also not run for extended periods at less than 50% of rated load due to maintenance issues[6].

[6] Running at less than 50% load leads to poor combustion and fouling of the engine, a condition known as “wet stacking.”

Discussions at the Study's kickoff meeting suggested that operating generators at 50% to 65% of rated loads is common in Operation Enduring Freedom (OEF)/Operation Iraqi Freedom (OIF), while historically, standard procedure was to operate at 60% to 80% of rated load. Analysis using both assumptions was performed to document the impact of hot weather operations.

3.2. Load Estimates

3.2.1. Documented Loads

Using the above assumptions, all documented and analogous loads were categorized by classification and support. By using TO/E from TFSMS (AAO from 5 June 2009), the loads and generating capacity of each unit were tabulated. The results for I, II, and III MEF are listed in Table 3.2-1. Note that these results are incomplete because of missing or ambiguous documentation described in Chapter 2 and because much ACE equipment is not covered in TFSMS. Total ACE requirements are given in Appendix G.

Table 3.2-1 Documented MEP loads for I, II, and III MEF in Kilowatts

I MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	3,454.4			834.9	11,623.9	15,913.2
REQUIRED	2,220.0				1,884.5	4,104.5
IMPORTANT	7,122.0	315.4		30.3	16,077.3	23,545.0
Total	12,796.4	315.4	0.0	865.2	29,585.8	43,562.8
II MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	3,452.9			811.2	11,196.7	15,460.8
REQUIRED	2,220.0				1,908.7	4,128.7
IMPORTANT	6,524.0	320.5		30.3	15,791.2	22,666.0
Total	12,196.9	320.5	0.0	841.5	28,896.6	42,255.4
III MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	2,303.9			592.9	6,685.4	9,582.2
REQUIRED	2,100.0				1,225.8	3,325.8
IMPORTANT	5,104.4	206.6		25.0	11,333.9	16,669.8
Total	9,508.3	206.6	0.0	617.9	19,245.1	29,577.8

3.2.2. Estimated Loads

To mitigate the impact of missing data, loads for collections of items employed in tents and shelters were estimated using planning factors from the Basic Communications Officer Course (BCOC) and FM 5-424, *Theater of Operations Electrical Systems*. The BCOC method uses tent/shelter lighting and the number of outlets to estimate the electrical load (not including ECUs). FM 5-424 provides both a different outlet algorithm and an algorithm based on a tent/shelter's area that can be used if a wiring description is unavailable. Note that these estimates take into account both typical equipment to be found in the tent/shelter and their duty cycles. The Load Estimates for the most common tent/shelters are given in Table 3.2-2. An adequate wiring description for the Expeditionary Shelters and the Modular Command Post System were unavailable. The estimates for these tent/shelters listed under BCOC were estimated as four times the FM 5-424 area-based estimate[7]. The Decontamination Shelter, C61242E, was assumed to have a single light fixture; no loads are mentioned in its ULSS. The area estimates for the Modular General Purpose Tent System, C34132F, were used in the analysis: the Hospital figure for the Medical Battalions and the dwellings figure for all other units. The BCOC estimates were used for the other tent/shelters.

Table 3.2-2 Load Estimation for Tent/Shelters

TAMCN	Item Name	Length	Width	Light fixtures	# moguls	# outlets	Area Est. (kW)	BCOC Est. (kW)
A00897G	SHELTER, NONEXPANDABLE							0.0
A22937G	SHELTER, RIGID WALL, MODULAR, EXTENDABLE	38.3	18.7	12	0	36	3.6	14.1
A22947G	SHELTER, NONEXPANDABLE	10	8	4	0	4	0.4	2.5
A23337G	SHELTER, TACTICAL, EXPANDABLE, TWO-SIDED	19.9	21.8	6	1	26	2.2	14.6
A23352B	SHELTER, 10FT, EMI, MAINT COMPLEX	10	8	4	0	16	0.4	9.0
A23362B	SHELTER, 20FT, EMI, MAINT COMPLEX	20	8	8	0	21	0.8	12.1
A23372B	SHELTER, 20FT, RIGID, MAINT COMPLEX	20	8	8	0	22	0.8	12.6
A23382B	SHELTER, 10FT, RIGID, MAINT COMPLEX	10	8	4	0	16	0.4	9.0
C00442F	EXPEDITIONARY SHELTER (SMALL)	15.5	15			12	1.2	4.65
C00452F	EXPEDITIONARY SHELTER (MEDIUM)	25	20.5			18	2.6	10.25
C21602B	COLLECTIVE PROTECTION SYSTEM (CPS), Modular General Purpose Tent System (MGPTS) (Medium)	36	18				1.9	2.04
C34102F	SHELTER HALF, TENT, OG							0.0

[7] A factor of four was chosen as being comparable to the ratio for the SHELTER, RIGID WALL, MODULAR, EXTENDABLE, A22937G.

TAMCN	Item Name	Length	Width	Light fixtures	# moguls	# outlets	Area Est. (kW)	BCOC Est. (kW)
C34112F	COMMAND POST SYSTEM, MODULAR, DESERT (MCPS)	11.4	11.4				.65	2.6
C34122F	COMMAND POST SYSTEM, MODULAR, GREEN	11.4	11.4				.65	2.6
C61242E	SHELTER, DECONTAMINATION			1				0.1
C64202F	TENT, SHELTER, MAINT							0.0
C34132F	TENT SYSTEM, GP, MODULAR, GREEN (MGPTS) - Dwellings	52	34	8			3.8	.8
C34132F	TENT SYSTEM, GP, MODULAR, GREEN (MGPTS) - Hospitals	52	34	8			1.4	.8
E00797B	MEX-26 MAINTENANCE SHELTER	32	26	4	3	8	.42	4.7

To employ these estimates, the Study Team identified the set of TAMCNs expected to be used in these tent/shelters and the ECUs typically associated with them. Since the current practice in OEF/OIF is to employ an ECU with every tent/shelter, that practice is reflected in the loads. The reader should be aware that allocating an ECU to each tent/shelter is not reflected in current doctrine or AAOs. The remaining TAMCNs were tabulated as before, resulting in the MEF load profiles in Table 3.2-3. Appendix E lists each TAMCN requiring electric power and whether or not it was used in a tent/shelter. (The estimated loads also include ECU requirements tabulated as described in the 2012 Estimated Loads shortfall estimates below.) Note that the load totals for the estimated loads are much larger than those for the documented loads.

Table 3.2-3 Estimated MEP loads for I, II, and III MEF in Kilowatts

I MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	3,430.4			814.9	9,921.0	14,166.2
REQUIRED	2,220.0				1,884.5	4,104.5
IMPORTANT	6,960.0	182.7		2,732.4	97,789.3	107,664.4
Total	12,610.4	182.7	0.0	3,547.3	109,594.8	125,935.2
II MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	3,428.9			791.2	10,654.7	14,874.7
REQUIRED	2,220.0				1,908.7	4,128.7
IMPORTANT	6,377.0	182.7		2,768.4	100,729.2	110,057.3
Total	12,025.9	182.7	0.0	3,559.6	113,292.5	129,060.7

III MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	2,287.9			582.9	5,398.7	8,269.5
REQUIRED	2,100.0				1,225.8	3,325.8
IMPORTANT	5,014.4	125.1		1,988.9	55,966.9	63,095.2
Total	9,402.3	125.1	0.0	2,571.8	62,591.4	74,690.5

3.2.3. 2020 Estimates

Future MEP requirements will depend on a number of factors including: new POR, broad based technical trends, and Marine Corps policy and priorities affecting use of equipment, especially ECUs. The Study Team addressed these issues by analyzing a range of possibilities.

The Study Team retrieved a list of approximately 970 projects from The Online Project Information Center (TOPIC). In order to determine the future POR of interest to this Study, the Study Team eliminated all the programs that currently (as of 5 June 2009) have an AAO (programs already in TFSMS are not considered "future" systems). Subsequently the Study Team reviewed each of the remaining individual programs to determine if it could impact power requirements. (Many projects could be eliminated based upon title alone, e.g., "FAMILY OF CARGO CONTAINERS," while others required research.) The result of this effort was a list of 61 POR likely to have an impact on future MEP requirements. These POR are listed in Appendix F. Note that the Study Sponsor data call to MARCORSYSCOM also requests information on "new" systems that may include or enhance projects in this list of POR for Phase 2 of the Study. The Study Team estimated the power requirements for the identified POR and determined the distribution of POR across the various load centers to assess their impact.

Additional programs or trends that may affect future MEP requirements include:

- Deployment of the Joint Light Tactical Vehicle, which is required to provide exportable power. JLTV will most likely impact systems which contain component vehicles and require dedicated power. Appendix H lists the systems, which include component vehicles, as provided by TFSMS, along with the power and generator support required.
- Trends in ECU efficiency/power requirements. SME at MARCORSYSCOM suggested that 10%-25% efficiency improvements are possible.
- Trends in efficiency improvements of computer equipment (e.g., based upon energy star standards). Some systems, e.g. servers, may absorb efficiency improvements into increased performance. However, up to 57 watts of power reductions over current MCHS systems may be realized for laptops and monitors.
- The proliferation of personal communications and electronic systems, which may drive an increase in battery charger requirements. However, small fuel cells are already available as replacements for some rechargeable batteries.
- Improved insulation for general purpose (GP) tents which drive ECU demand.

- Renewable energy sources that may augment traditional generators.

The first and last factors can be addressed independently. The JLTV may substitute for some generators, but does not affect demand. Renewable sources will reduce fuel consumption, but also won't reduce demand. The remaining factors all affect MEP requirements through demand changes.

The Study Team estimated the ECU requirements for the Modular GP Tent System (MGPTS), C3413, using an online calculator[8] and adjusted for the differences between the tent and a permanent civilian structure. The main difference is the insulation R-value. The MGPTS has insulation of approximately R-2.2 and requires a 120k BTU/hr ECU. A future tent with insulation to R-3.3 could reduce cooling requirements to 96k BTU/hr. The Marine Corps does not currently deploy a 96k BTU/hr ECU. Employing two smaller units would result in a larger peak power than the B0010 120k BTU/hr system requires. Therefore, fuel use would be the main measurable impact. Because there are thousands of these tents in the inventory, this fuel reduction could be significant.

The range of future requirements can be illustrated by the cases listed in Table 3.2-4.

Table 3.2-4 Basis of 2020 Estimates

	High Demand	Moderate Demand	Low Demand
ECU Improvement	10%	25%	25%
MCHS Energy Consumption	Current	Current	Energy Star
Battery Chargers	2X Current	1X Current	Fuel Cell
MGPTS Insulation (R value)	2.2	2.2	3.3

Tables 3.2-5 through 3.2-7 show the aggregate demand, by MEF, resulting from these cases.

Table 3.2-5 2020 High Demand loads for I, II, and III MEF in Kilowatts

I MEF						
	DEDICATED	**EXCLUSIVE-Hertz**	**EXCLUSIVE-Volts**	**EXCLUSIVE-WYE**	**GRID**	**Total**
CRITICAL	6,315.5	0.0	0.0	836.9	9,753.4	16,905.8
REQUIRED	2,220.0	0.0	1,184.0	0.0	1,622.4	5,026.4
IMPORTANT	11,072.1	103.7	0.0	2,793.8	88,609.0	102,578.6
Total	19,607.6	103.7	1,184.0	3,630.7	99,984.8	124,510.8
II MEF						
	DEDICATED	**EXCLUSIVE-Hertz**	**EXCLUSIVE-Volts**	**EXCLUSIVE-WYE**	**GRID**	**Total**
CRITICAL	6,349.1	0.0	0.0	813.2	10,574.1	17,736.4
REQUIRED	2,220.0	0.0	1,184.0	0.0	1,679.2	5,083.2
IMPORTANT	9,503.2	103.7	0.0	2,799.1	92,867.7	105,273.6
Total	18,072.3	103.7	1,184.0	3,612.3	105,121.0	128,093.2

[8] http://coolingcalc.whirlpool.com/calculator/default.asp, accessed 7 August 2009.

III MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	4,723.0	0.0	0.0	574.9	5,250.6	10,548.5
REQUIRED	2,100.0	0.0	1,120.0	0.0	1,089.1	4,309.1
IMPORTANT	7,874.8	103.7	0.0	2,006.9	50,655.1	60,640.5
Total	14,697.7	103.7	1,120.0	2,581.9	56,994.8	75,498.0

Table 3.2-6 2020 Moderate Demand loads for I, II, and III MEF in Kilowatts

I MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	6,086.4	0.0	0.0	824.9	9,355.2	16,266.4
REQUIRED	2,220.0	0.0	1,184.0	0.0	1,622.4	5,026.4
IMPORTANT	11,033.3	86.4	0.0	2,793.8	77,597.3	91,510.8
Total	19,339.6	86.4	1,184.0	3,618.7	88,574.8	112,803.6
II MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	6,121.6	0.0	0.0	801.2	10,089.6	17,012.4
REQUIRED	2,220.0	0.0	1,184.0	0.0	1,679.2	5,083.2
IMPORTANT	9,468.1	86.4	0.0	2,799.1	81,348.2	93,701.8
Total	17,809.7	86.4	1,184.0	3,600.3	93,117.0	115,797.4
III MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	4,554.0	0.0	0.0	562.9	4,973.1	10,090.0
REQUIRED	2,100.0	0.0	1,120.0	0.0	1,089.1	4,309.1
IMPORTANT	7,850.0	86.4	0.0	2,006.9	44,636.8	54,580.1
Total	14,504.0	86.4	1,120.0	2,569.9	50,699.0	68,979.2

Table 3.2-7 2020 Low Demand loads for I, II, and III MEF in Kilowatts

I MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	6,086.4			824.9	9,319.6	16,230.8
REQUIRED	2,220.0		1,184.0		1,622.4	5,026.4
IMPORTANT	11,033.3	86.4		2,793.8	77,588.9	91,502.4
Total	19,339.6	86.4	1,184.0	3,618.7	88,530.8	112,759.6
II MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	6,121.6	0.0	0.0	801.2	10,051.0	16,973.8
REQUIRED	2,220.0	0.0	1,184.0	0.0	1,679.2	5,083.2
IMPORTANT	9,468.1	86.4	0.0	2,799.1	81,341.0	93,694.6
Total	17,809.7	86.4	1,184.0	3,600.3	93,071.2	115,751.6
III MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	4,554.0	0.0	0.0	562.9	4,936.3	10,053.3
REQUIRED	2,100.0	0.0	1,120.0	0.0	1,089.1	4,309.1
IMPORTANT	7,850.0	86.4	0.0	2,006.9	44,633.2	54,576.5
Total	14,504.0	86.4	1,120.0	2,569.9	50,658.6	68,938.9

3.2.4. Modified Cases

After the five cases described above were reviewed by the Study Sponsor, SME indicated that two of the assumptions were unrealistic and should be modified. Specifically, the first assumption requiring modification was that all ECUs associated with critical loads should be considered critical. The initial assumption was that only ECUs that were components of critical loads would be critical. The Study Team implemented this new assumption by treating all ECUs supporting critical Loads as components.

The second assumption requiring modification concerned the treatment of improved future ECU efficiency. The Study Team initially assumed that efficiency improvements would manifest in reduced power consumption. SME indicated that the primary impact of ECU improvements would be to allow operation in higher ambient temperatures and that power consumption would likely remain the same as current systems. This second revised assumption meant that the 2020 cases would have negligible differences in required power.

The Study team revised the 2012 Estimated and 2020 Moderate cases to reflect the updated assumptions. These two newer cases are labeled 2012 Planning Factor Loads and 2020 Loads. The Load totals, by MEF, are shown in Tables 3.2-8 and 3.2-9. Note that all Exclusive-Hertz requirements disappear because all 400 Hz systems (now including all supporting ECUs) require dedicated power.

Table 3.2-8 2012 Planning Factor Loads for I, II, and III MEF in Kilowatts

I MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	3,775.6			894.9	10,628.1	15,298.5
REQUIRED	2,220.0				1,884.5	4,104.5
IMPORTANT	7,122.0			2,732.4	97,734.7	107,589.1
Total	13,117.6	0.0	0.0	3,627.3	110,247.3	126,992.2
II MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	3,776.1			871.2	11,241.8	15,889.0
REQUIRED	2,220.0				1,908.7	4,128.7
IMPORTANT	6,524.0			2,768.4	100,662.1	109,954.5
Total	12,520.1	0.0	0.0	3,639.6	113,812.5	129,972.2
III MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	2,522.5			662.9	5,835.8	9,021.2
REQUIRED	2,100.0				1,225.8	3,325.8
IMPORTANT	5,104.4			1,988.9	55,872.3	62,965.5
Total	9,726.9	0.0	0.0	2,651.8	62,933.9	75,312.5

Table 3.2-9 2020 Loads for I, II, and III MEF in Kilowatts

I MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	6,804.6			924.9	10,314.5	18,044.0
REQUIRED	2,220.0		1,184.0		1,622.4	5,026.4
IMPORTANT	11,098.2			2,793.8	95,556.9	109,448.9
Total	20,122.8	0.0	1,184.0	3,718.7	107,493.8	132,519.3
II MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	6,839.1			901.2	11,152.7	18,893.0
REQUIRED	2,220.0		1,184.0		1,679.2	5,083.2
IMPORTANT	9,526.8			2,799.1	100,196.0	112,521.9
Total	18,585.9	0.0	1,184.0	3,700.3	113,027.9	136,498.1
III MEF						
	DEDICATED	EXCLUSIVE-Hertz	EXCLUSIVE-Volts	EXCLUSIVE-WYE	GRID	Total
CRITICAL	5,119.1			662.9	5,620.7	11,402.7
REQUIRED	2,100.0		1,120.0		1,089.1	4,309.1
IMPORTANT	7,891.4			2,006.9	54,381.9	64,280.2
Total	15,110.5	0.0	1,120.0	2,669.9	61,091.7	79,992.0

3.3. Shortfall Analysis

3.3.1. Load Centers

The loads listed above cannot be supported in aggregate; they must be supported across a distributed battlefield. As a surrogate for a specific geographic laydown, the Study used company level AAOs, with MEP demand categorized by classification and support, as defining “load centers” that must be separately supported. Each load center must have an appropriately sized generator or generators.

Many companies geographically disperse or deploy detachments during operations so that their load centers should be further subdivided. The Study Team examined large load centers (greater than 180 kW for documented loads), along with the unit’s mission statement, and determined that a number of them are support units and would normally deploy some of their equipment to collocate with their supported units. The number of detachments and the equipment distribution depends on the unit. The process for performing this subdivision is described in Appendix D. Figure 3.3-1 shows the distribution of load center sizes based on the 2012 Documented Loads, 2012 Estimated Loads, and the 2020 cases. These load centers, and the resulting MEP and ECU requirements that follow, are for the Fleet Marine Force (FMF), the three active MEFs and the reserves (MARFORRES).

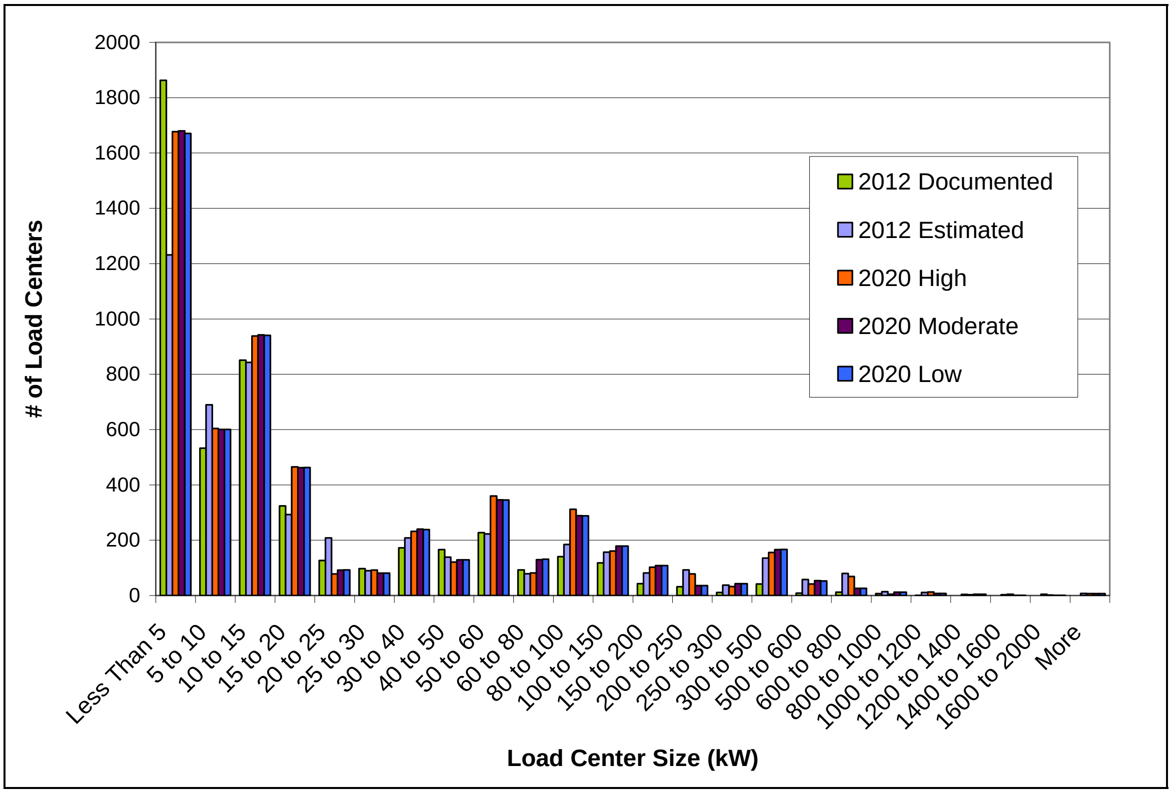

Figure 3.3-1. FMF Load Center Size Distribution

The same load center approach was applied to the modified cases, 2012 Planning Factor Loads and 2020 Loads. Figure 3.3-2 shows the load center distribution for these cases with the 2012 documented case included as reference.

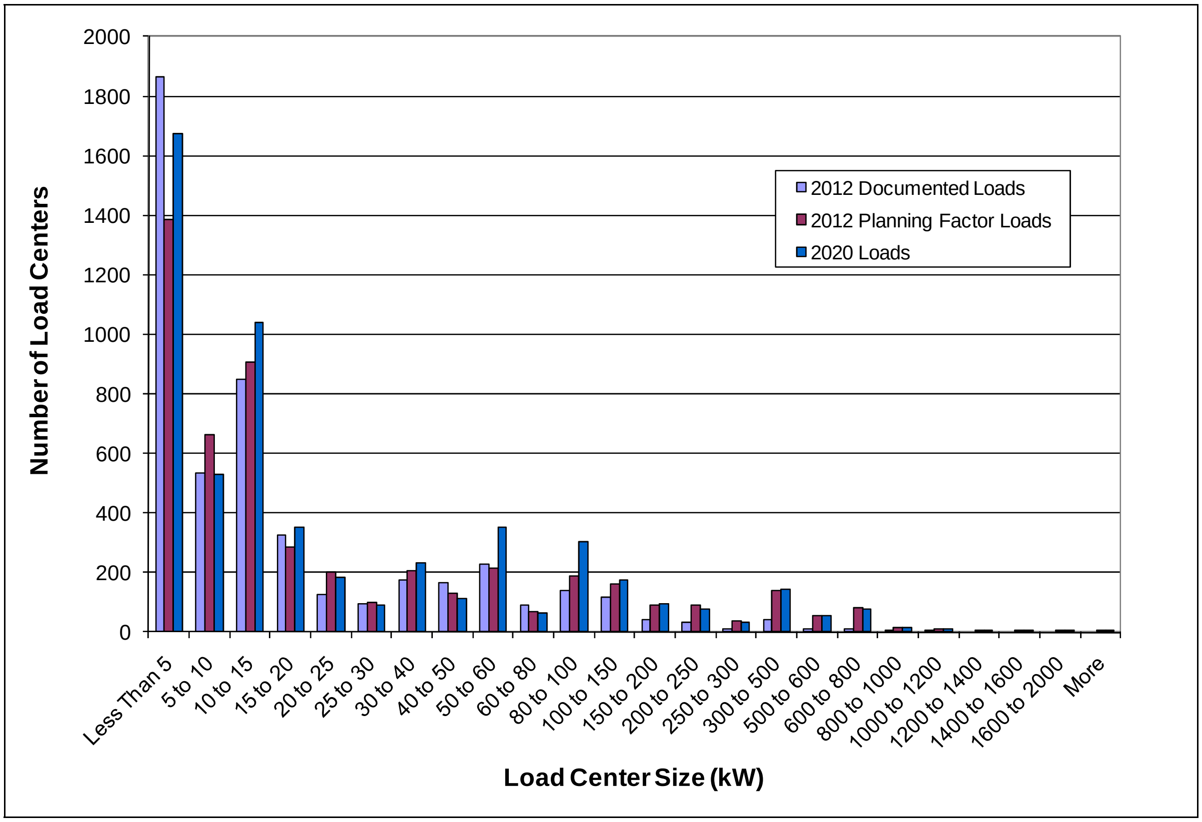

Figure 3.3-2 Revised FMF Load Center Size Distribution

3.3.2. Generator Sizing Rules

The assignment of a set of generators to a load must take into account:

- **Utilization ratio**: the study sized generators so that loads are between 50 and 65% or between 60% and 80% of rated generator power (any range can be investigated in Phase II).
- **Efficiency**: larger generators are usually more fuel efficient. The Study Team researched generator fuel consumption as a function of load.
- **Multiple Generators**[9]: Multiple generators may require more support than a single larger unit.
- **Dummy Loads**: "Dummy," including unauthorized, loads could reduce paralleling or allow use of a more efficient generator. This option is discussed below.

The Study Team coded an algorithm that assigns the largest possible generator to a load center. The results for a hypothetical set of load centers are shown in Table 3.3-1. Utilization ratios of 60% to 80% result in one each fewer 2 kW and 100 kW generators and one more 10 kW generator for this collection of load centers than the baseline 50%

[9] "Paralleling" is a term used to describe using two or more generators simultaneously on a grid. Current smaller generators are not capable of operating simultaneously on the same grid. Future generators and/or distribution equipment may provide this capability. If more than one generator is required for a load center, small load centers currently must be subdivided so that generators less than 60 kW are not paralleled.

to 65% utilization ratios. Note that if 40 kW of rated power is called for, this algorithm assigns 10 and 30 kW generators rather than two 20 kW sets. Also, note that adding a dummy load to several of these example load centers would result in fewer total generators.

Table 3.3-1 Generator assignment examples for different utilization ratios

50% - 65%							
	Generator Rated Power (kW)						
Load (kW)	2	3	10	20	30	60	100
2		1					
4	1	2					
6			1				
8		1	1				
10				1			
15					1		
20			1		1		
25				1	1		
30						1	
40				1		1	
50							1
60							1
60% - 80%							
	Generator Rated Power (kW)						
Load (kW)	2	3	10	20	30	60	100
2		1					
4		2					
6			1				
8			1				
10		1	1				
15				1			
20					1		
25			1		1		
30				1	1		
40						1	
50				1		1	
60							1

After discussions at In-Progress Review #2, the Study Team modified the script to:

1. First assign the largest generators consistent with the stated utilization ratio limits.
2. If more than one generator is required, relax the minimum utilization to 50% and use the new generator assignment if fewer generators are required. (This has no effect if the stated utilization minimum is already 50%.)
3. If more than one generator still is required, add up to 2 kW of dummy loads. Use this newest generator assignment only if it results in fewer generators than step 2.

Note that utility officers currently do not install dummy loads in order to use a larger generator. However, in practice non-T/E equipment is frequently supported by MEP.

Without dummy loads, the four kilowatt load requires two or three generators. Plugging in a coffee pot or a few additional lights would allow a single 10 kW generator to be used.

The modified results for the hypothetical list of loads are shown in Table 3.3-2. This modified sizing algorithm was applied to each load center to determine the required number of each generator type.

Table 3.3-2 Modified generator assignment examples

50% - 65%							
	Generator Rated Power (kW)						
Load (kW)	2	3	10	20	30	60	100
2		1					
4			1				
6			1				
8				1			
10				1			
15					1		
20			1		1		
25				1	1		
30						1	
40				1		1	
50							1
60							1
60% - 80%							
	Generator Rated Power (kW)						
Load (kW)	2	3	10	20	30	60	100
2		1					
4			1				
6			1				
8			1				
10				1			
15				1			
20					1		
25			1		1		
30						1	
40						1	
50							1
60							1

3.3.3. Shortfall Estimates

3.3.3.1. 2012 Documented Loads Shortfall

The Study Team estimated the number of each type of generator required to support the load centers documented in Section 3.2 with the assumptions listed in Section 3.1.1. Appendix D provides the power requirements for each individual load center. In this estimate, only TFSMS-derived ECUs were assumed. Estimates were made for both 50%-65% and 60%-80% utilization ranges. A number of component generators are not one of the standard sizes. These generators are grouped together in Figure 3.3-3 and labeled Non-Standard. Component GETTs in Combat Operations Centers (COC) are listed as such, but no other 20 kW generator requirements are identified as GETTs. The required numbers include backup systems for critical loads. The required generators are compared to the AAO, rather than on-hand totals, since the ultimate disposition of gear acquired in-theater using supplemental funds is not known.

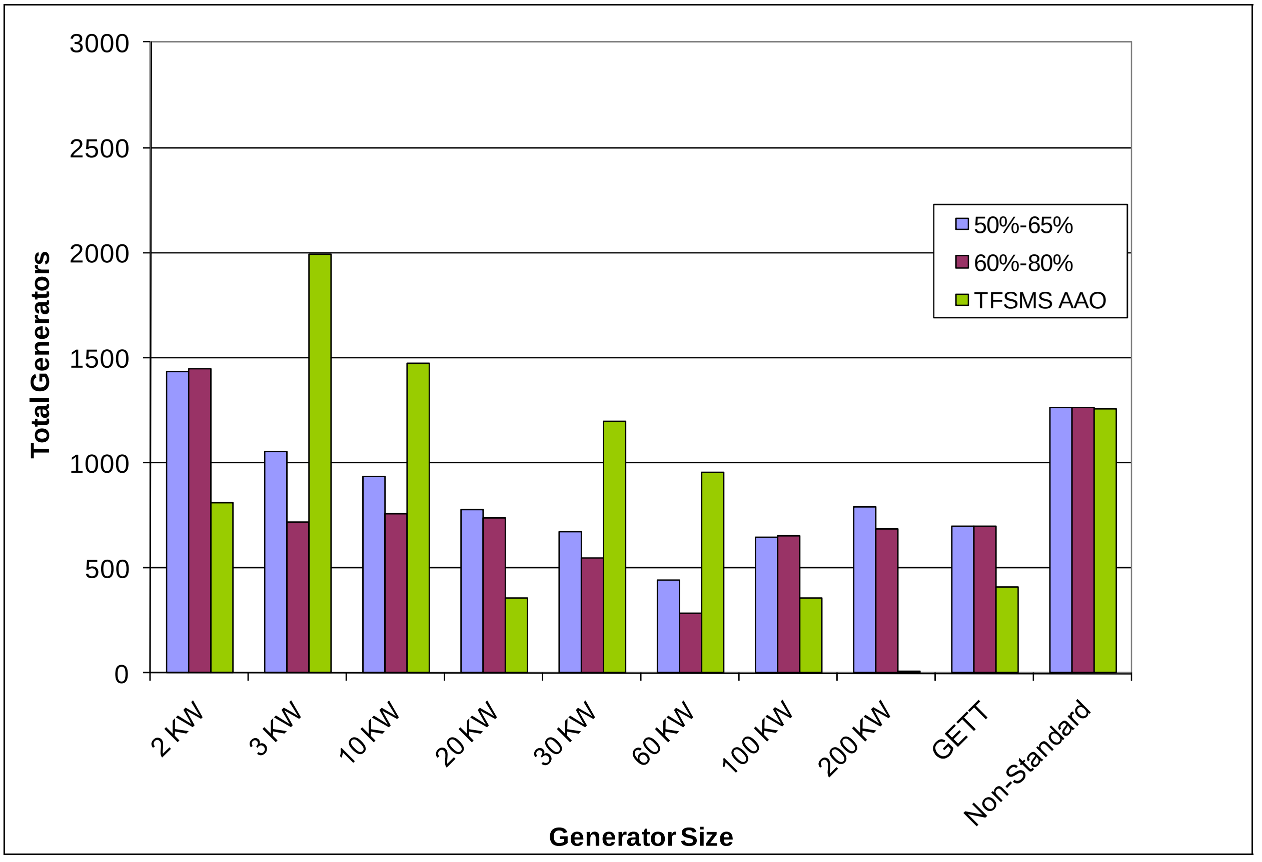

Figure 3.3-3. FMF Comparison of Generator Requirements to AAO for 2012 Documented Loads

3.3.3.2. 2012 Estimated Loads Shortfall

The Study Team estimated the number of each type of generator required to support the tent/shelter-based estimated load centers documented in Section 3.2 with the assumptions listed in Section 3.1.1. Appendix D provides the power requirements for each individual load center. In this estimate, ECUs were assigned to each tent/shelter based on guidance found in the tent/shelter's documentation. Estimates were made for both 50%-65% and 60%-80% utilization ranges and are shown in Figure 3.3-4. The required numbers include backup systems for critical loads.

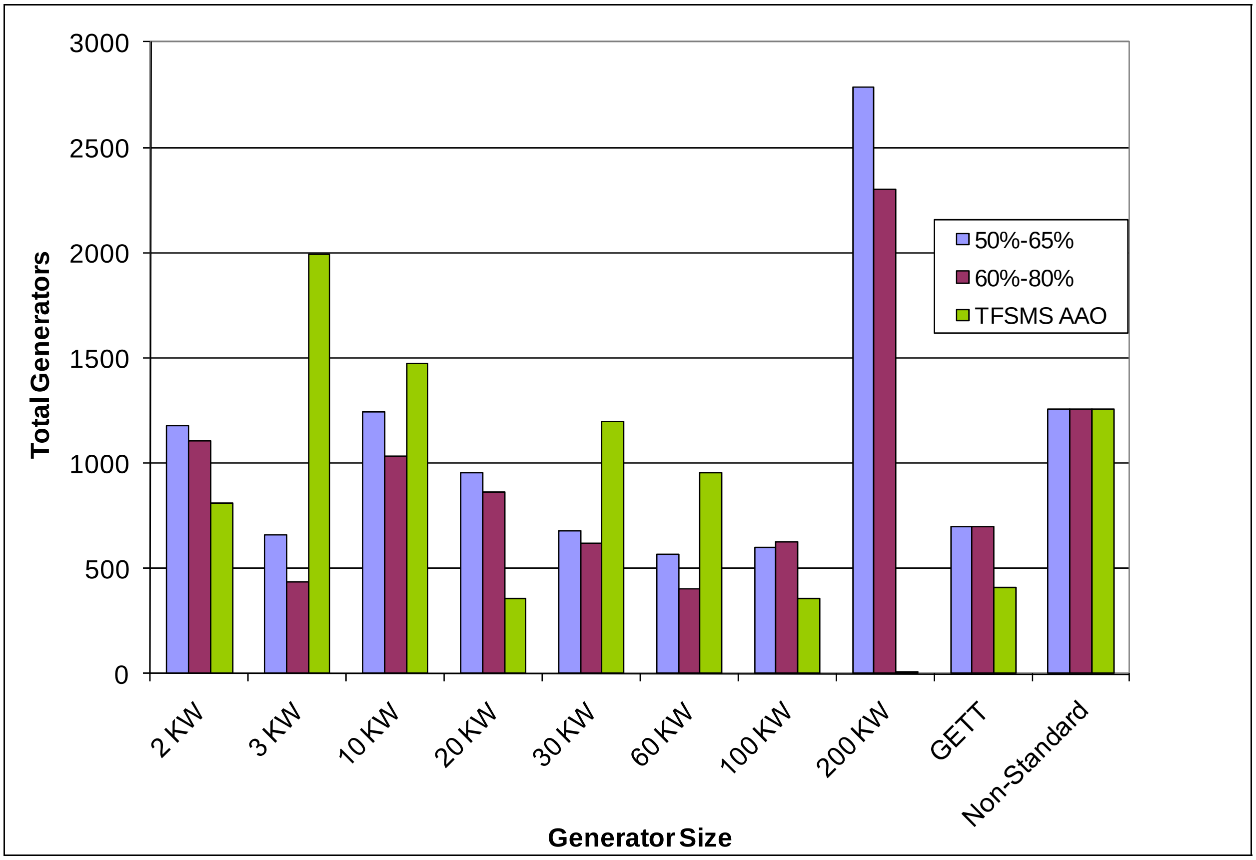

Figure 3.3-4. FMF Comparison of Generator Requirements to AAO for 2012 Estimated Loads

3.3.3.3. 2020 High Demand Shortfall

In the 2020 High Demand case, the requirement for 200 kW generators is less than for the 2012 estimated case because of the assumed improvement in ECU efficiency. The large number of ECUs to support command post and GP tents drives demand. Note the TFSMS assigned 845 GP tents to the three MEF Headquarters Groups, requiring 444 200 kW generators just for these three load centers. Shortfalls are shown in Figure 3.3-5.

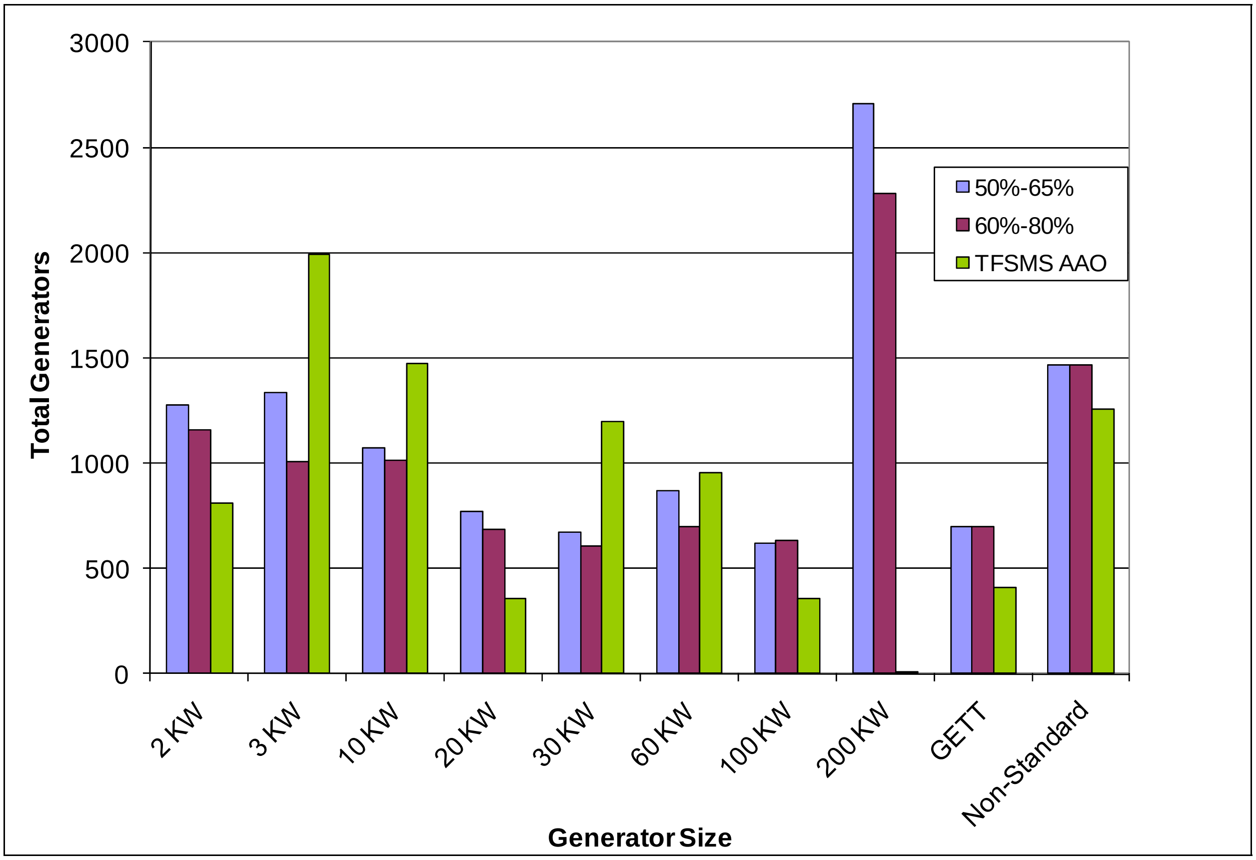

Figure 3.3-5. FMF Comparison of Generator Requirements to AAO for 2020 High Demand

3.3.3.4. 2020 Moderate Demand Shortfall

The main difference between the 2020 High and Moderate cases is the further improvement in ECU efficiency. The improvement from 10% to 25% is the main reason for a nearly 300 generator reduction in requirements for 200 kW sets.

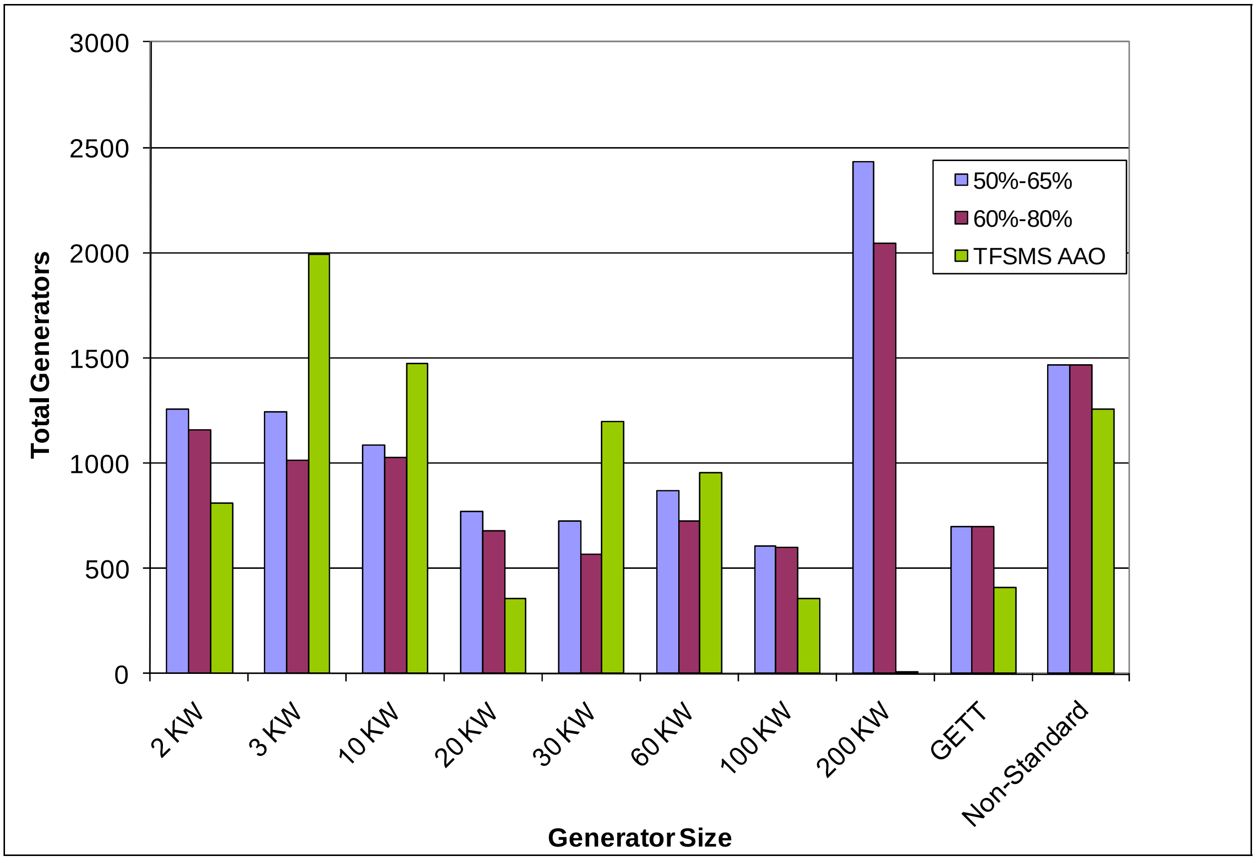

Figure 3.3-6. FMF Comparison of Generator Requirements to AAO for 2020 Moderate Demand

3.3.3.5. 2020 Low Demand Shortfall

The biggest difference between the 2020 Moderate and Low Demand cases is the improved insulation for the GP tents. However, since a 120k BTU/hr ECU is still required, this improvement would only manifest in reduced fuel consumption. The Energy Star monitors and reduced battery chargers have a very small effect.

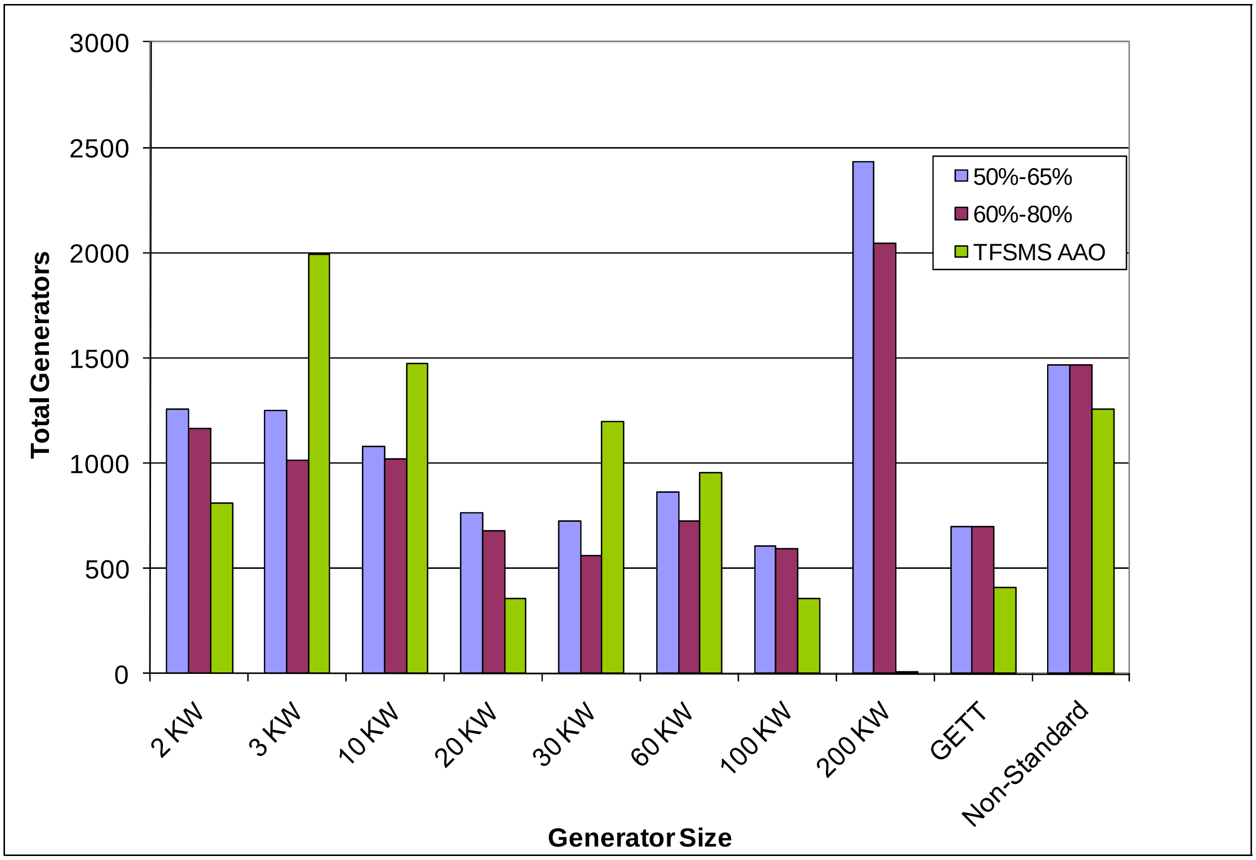

Figure 3.3-7. FMF Comparison of Generator Requirements to AAO for 2020 Low Demand

3.3.3.6. 2012 Planning Factor Loads Shortfall

For the modified cases, the Study Team used the same procedure as earlier to estimate the number of each type of generator required to support the tent/shelter-based estimated load centers documented in Section 3.2 with the assumptions listed in Section 3.1.1. In this estimate, ECUs were assigned to each tent/shelter based on guidance found in the tent/shelter's documentation. ECUs supporting critical loads in this estimate were included in the critical load center. Estimates were made for both 50%-65% and 60%-80% utilization ranges and are shown in Figure 3.3-8. The required numbers include backup systems for critical loads.

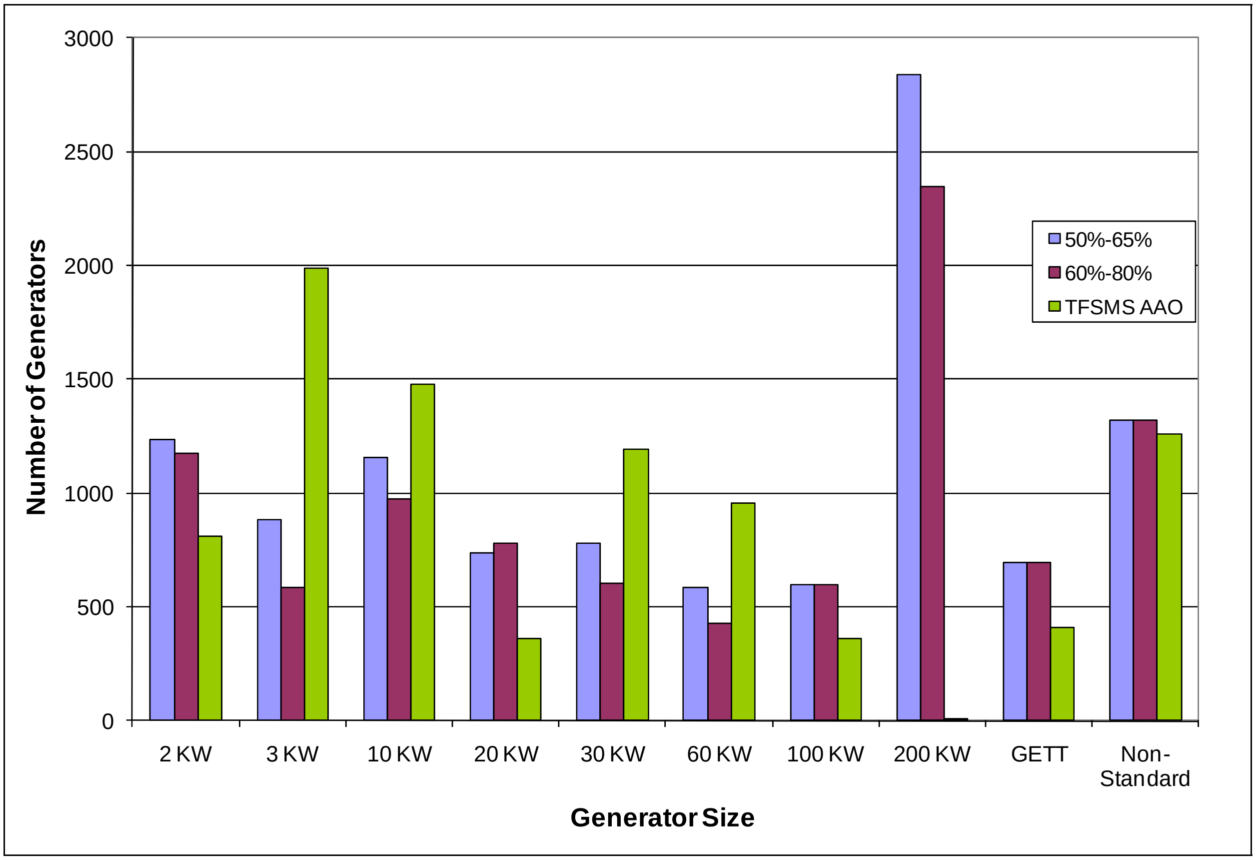

Figure 3.3-8 FMF Comparison of Generator Requirements to AAO for 2012 Planning Factor Loads

3.3.3.7. 2020 Loads Shortfall

Also in this modified case, ECUs supporting critical loads were included in the critical load center. Unlike the initial 2020 cases, ECUs are assumed to consume the same power as current systems of the same rated cooling capacity. Estimates were made for both 50%-65% and 60%-80% utilization ranges and are shown in Figure 3.3-9. The required numbers include backup systems for critical loads.

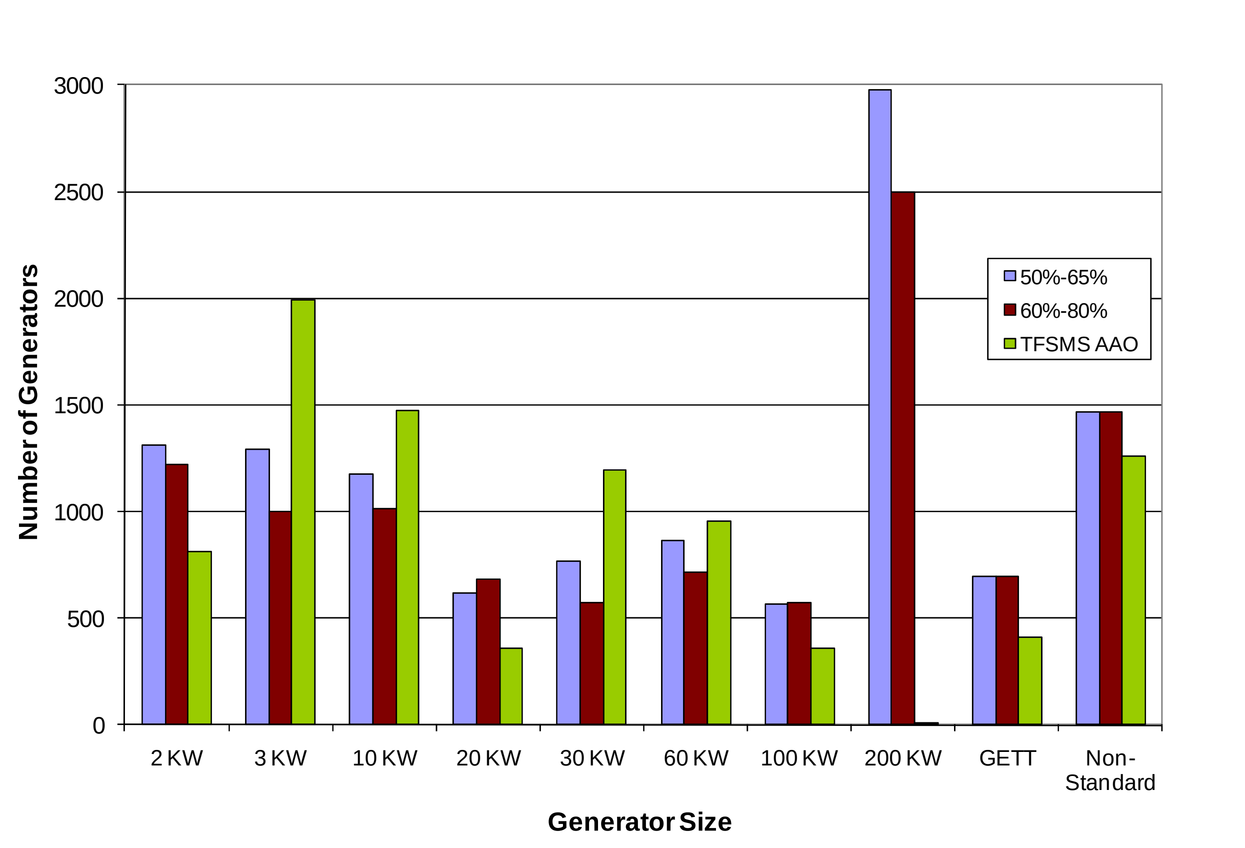

Figure 3.3-9 FMF Comparison of Generator Requirements to AAO for 2020 Loads

3.3.3.8. Shortfall Summary

The shortfall results for the five initial cases are summarized in Figure 3.3-10. The more detailed results above show adequate AAO[10] quantities of 3, 10, 30, and 60 kW generators and shortfalls for all other sizes. The low number of 200 kW generators in the AAO may be due to mobility requirements. One SME stated that ship to shore connector considerations in amphibious operations planning limits the utility of 200 kW systems. Also, if additional load data becomes available in Phase II, some of the smallest load centers may increase enough to warrant a larger generator(s).

[10] Recall that the analysis is based on the TFSMS AAO as of 5 June 2009.

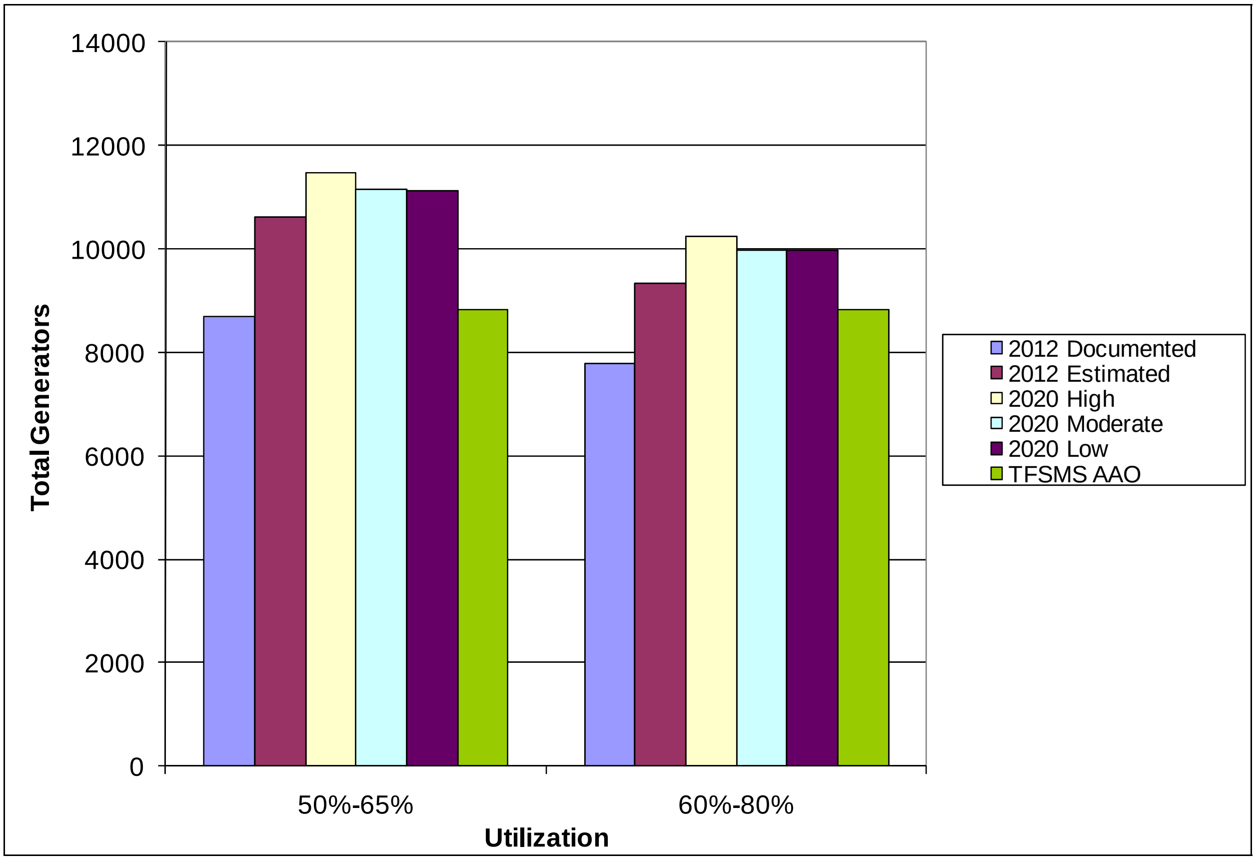

Figure 3.3-10 FMF Comparison of Total Generator Requirements to the AAO for the Initial Five Cases

The shortfall results for the 2012 documented case, along with the two modified cases—2012 Planning Factor Loads and 2020 Loads–are summarized in Figure 3.3-11. The more detailed results above show adequate AAO quantities of 3, 10, 30, and 60 kW generators and shortfalls for all other sizes.

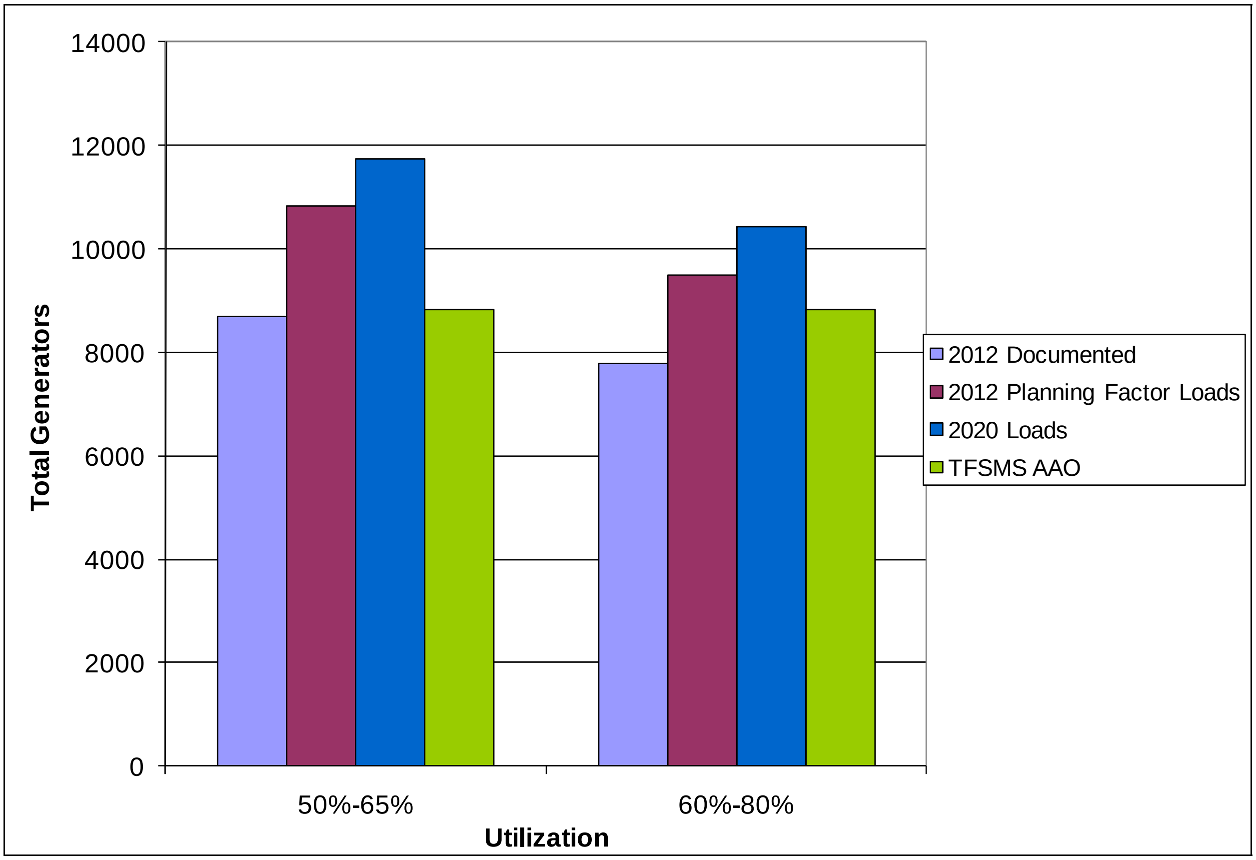

Figure 3.3-11 FMF Comparison of Total Generator Requirements to the AAO for the Modified Cases

3.3.4. JLTV Impact

JLTV is required to provide between 10 kW and 30 kW of exportable electrical power. Since a design has not been chosen, the Study Team analyzed both the minimum and maximum values. Because each vehicle fulfills a mission that may preclude the provision of power to other systems, the Study Team assumed that only TAMCNs with component HMMWVs and MEP requirements are candidates for replacing a portion of the required MEP. Not all TAMCNs having component HMMWVs can be used this way. For example, some tactical radars are required to operate separately from their prime mover. All the TAMCNs judged suitable for JLTV power export are listed in Appendix H, along with the associated load centers and required generators for 60%-80% utilization. The impact of substituting JLTV exported power for MEP is summarized in Figure 3.3-12 for the initial 2020 cases. The majority of load centers affected, all but 37, require dedicated power. The affected load centers without dedicated power happen to require the same number of generators in all three demand cases. With 10 kW of exportable power, JLTV can displace approximately 480 generators. With 30 kW of exportable power, the number of displaced generators increases to approximately 712. These numbers include backup requirements. In addition to the reduced number of generators, some of the remaining requirements are for smaller generators.

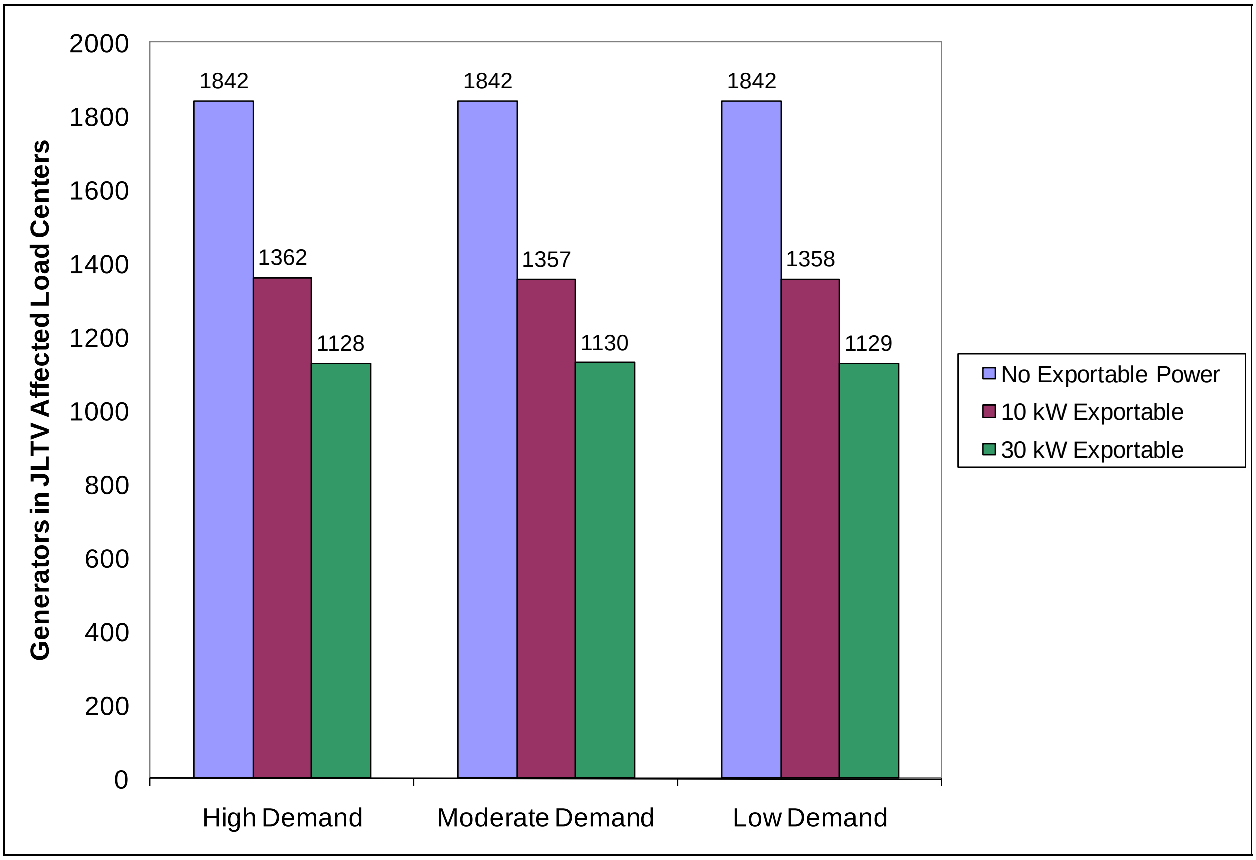

Figure 3.3-12 FMF JLTV Impact on 2020 MEP Requirements

3.3.5. Fuel Consumption Estimates

The Study Sponsor provided fuel consumption curves for some types of generators that allowed a comparison of fuel consumption for some load centers using different utilization ratios. Data was provided for the 10 kW, 30 kW, 60 kW, and 100 kW generators, so comparisons were possible for load centers between 45 and 98 kW[11]. There were 263 such load centers in the 2012 Planning Factor Loads case. Figure 3.3-13 shows that more closely matching the generators to the load by utilizing them at 60% to 80% could save 4% in fuel.

[11] This range of load centers required, in all cases, generators of only those sizes for which data was available.

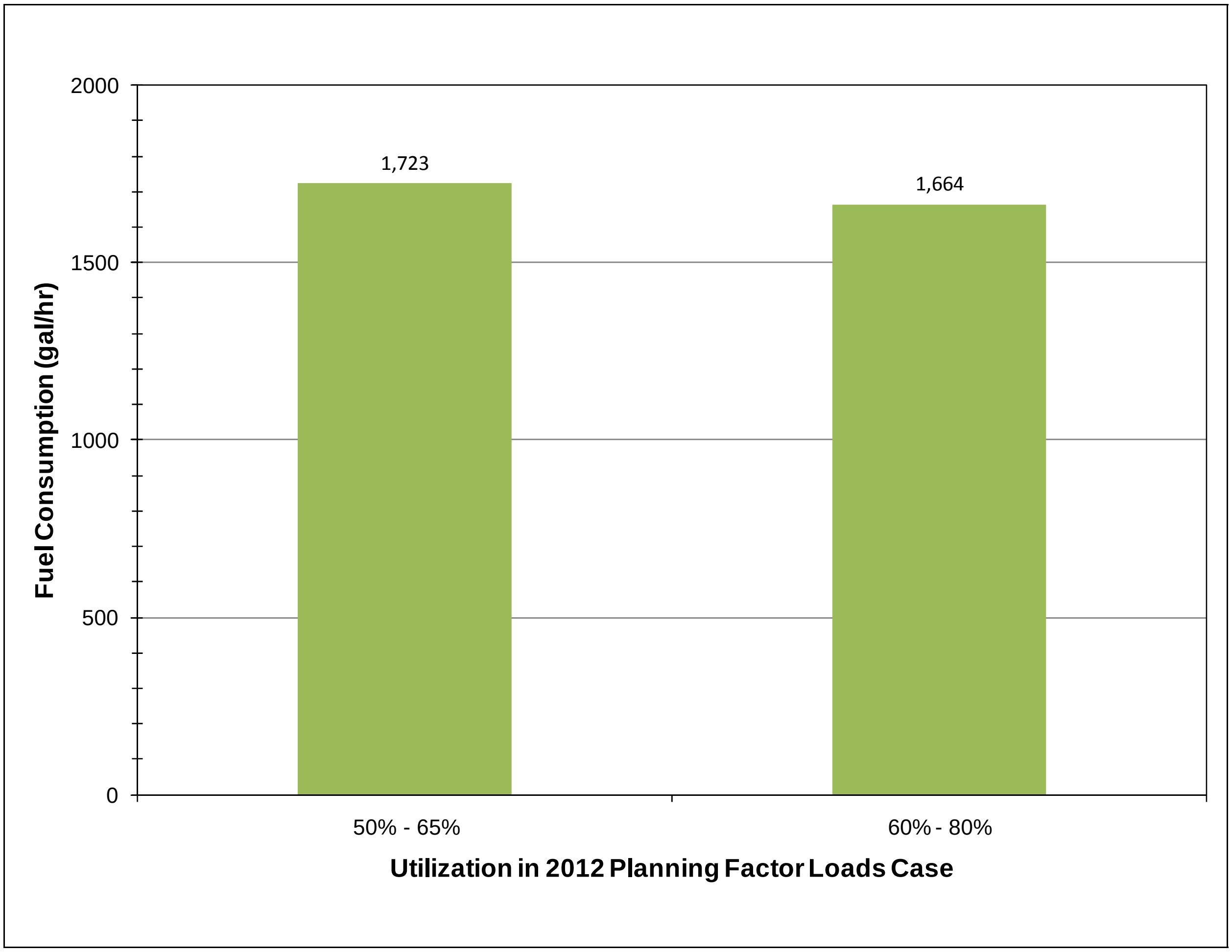

Figure 3.3-13 Estimated Fuel Consumption for Load Centers between 45 kW and 98 kW

3.4. Gap Analysis

The Marine Corps currently deploys eight standard generator sizes[12]. Given the current suite of standard generators, the existing load centers frequently require more than one generator. Multiple generators supporting a single load center increase the maintenance burden and the complexity of power distribution.. To avoid multiple generators, if the allowed capacity utilization is 60% to 80%, then the ratio of generator sizes should be no more than 6:8. This ratio is approached by the 2 kW and 3 kW sizes, but the other ratios are far from ideal. In order to reduce the need for multiple generators to support a load center, the Marine Corps could acquire a new size of generator. The optimum new generator size depends on the distribution of load center sizes.

The Study Team addressed this question by postulating a series of possible new sizes, applying the same generator sizing algorithm used in the shortfall analysis, and comparing generator totals. The process was repeated for each candidate generator size, one at a time.

[12] Some end items have component generators of a unique size. Only the standard non-component generators are part of the gap analysis.

3.4.1. 2012 Cases

The FMF results are plotted in Figure 3.4-1 for 2012 Documented Loads and Figure 3.4-2 for 2012 Estimated Loads. Each point on a curve in this figure represents the Fleet-wide generator requirement that would result from allowing the deployment of generators of the corresponding size, in addition to the current eight standard sizes. The data for these curves are included in Appendix D. Intuitively, the best gap-filler should be about half way between two existing sizes. This instinct is approximately correct, but the size yielding the minimum number of generators in any gap depends in detail on the load center distribution.

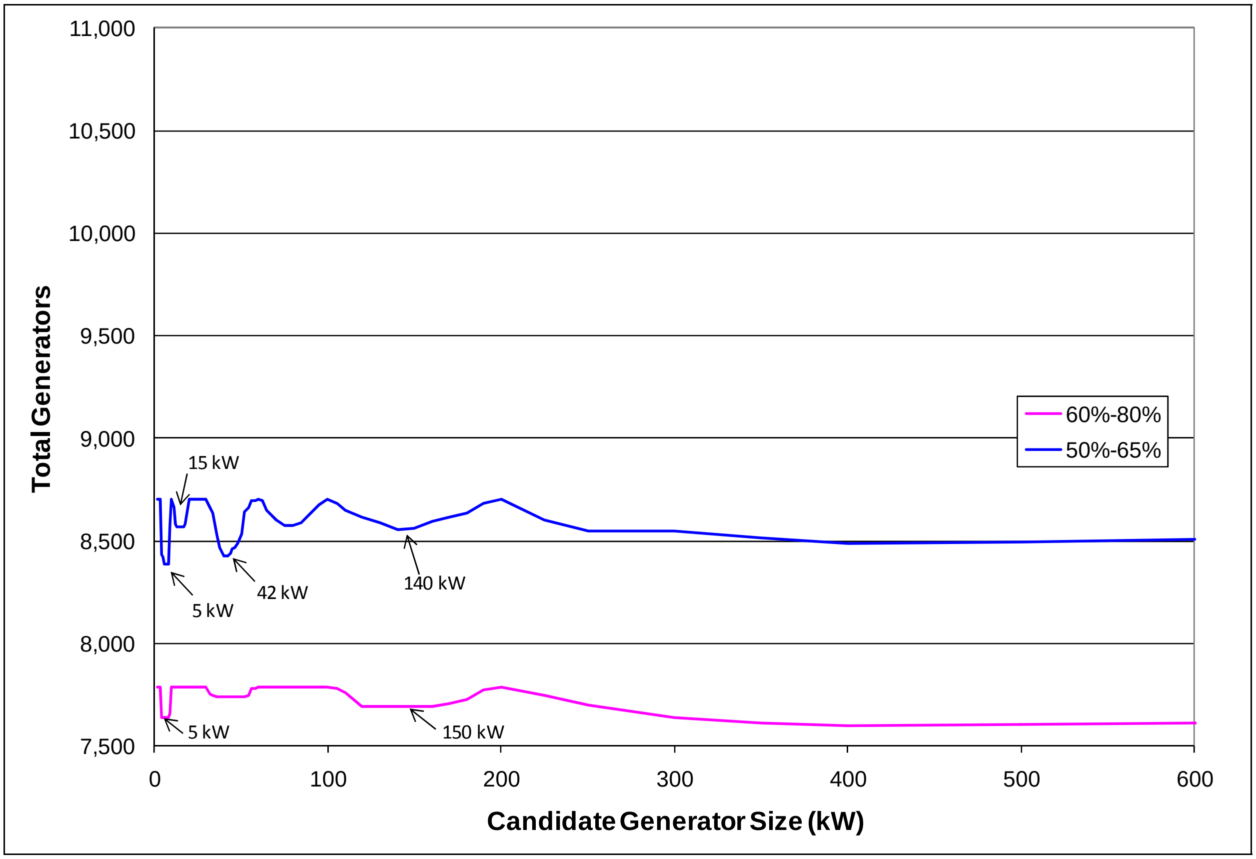

Figure 3.4-1. 2012 Documented Loads FMF Gap Analysis

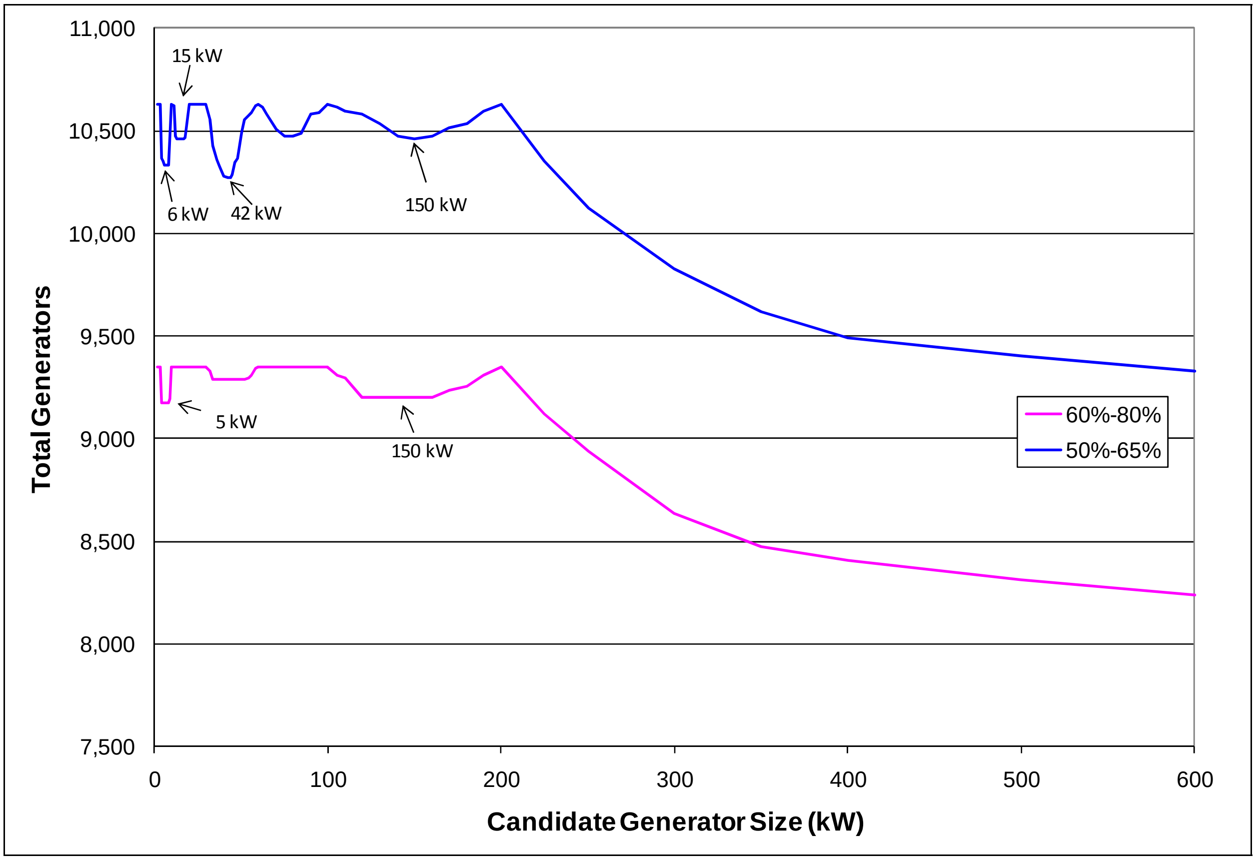

Figure 3.4-2. 2012 Estimated Loads FMF Gap Analysis

The large number of ECUs supporting tents/shelters in the 2012 Estimated case results in a requirement for over 2300 200 kW generators in relatively few very large load centers. These load centers would benefit from the very large candidate sizes. However, the deploying generators of this size would require new distribution equipment. The Army considers generators larger than 200 kW to be non-tactical,[13] therefore these options are not presented for the 2020 cases. Because most load centers are fairly small in the 2012 Documented Loads case, the most advantageous gap-fillers tend to be in the 3 kW to 10 kW gap or the 10 kW to 20 kW gap. The exception is for low utilization (50%-65%) in 2012 Estimated Loads case. The 2012 Estimated Loads case has larger load centers than 2012 Documented Loads case and low utilization implies generally larger generators. The best gap-filler for this combination is 40 kW.

3.4.2. 2020 Cases

The 2020 cases all require slightly more generators than the 2012 estimated case, but the FMF gap analysis shows a similar shape. For the 2020 High Demand case shown in Figure 3.4-3, requirements assuming 50%-65% utilization are reduced for a 7 kW, 15 kW, 42 kW and 150 kW gap fillers. The benefit of the 42 kW system rivals that of the 7 kW system. For 60%-80% utilization, the benefit of the 15 kW system disappears as in the 2012 cases and the benefit of the 42 kW system is greatly reduced.

[13] FM 3-34.480, ENGINEER PRIME POWER OPERATIONS, April 2007.

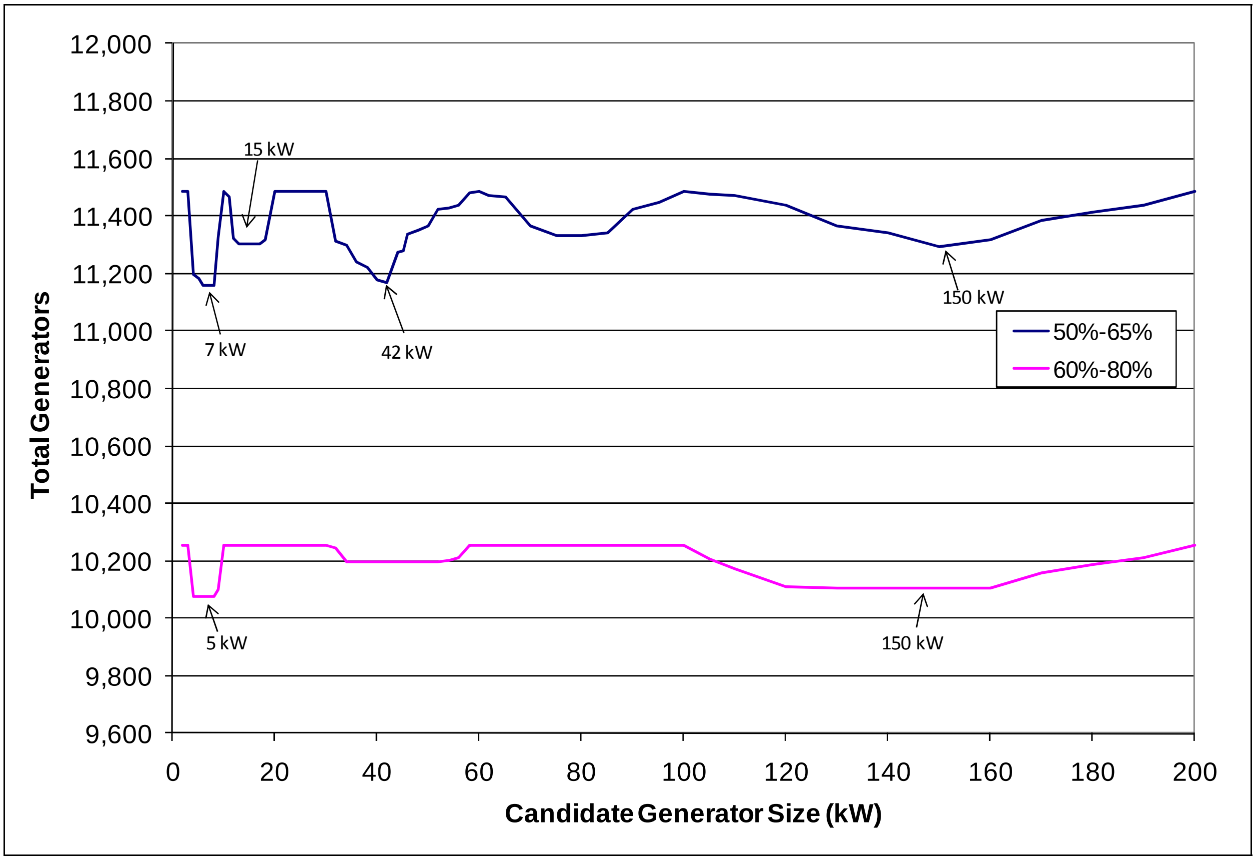

Figure 3.4-3.2020 High Demand FMF Gap Analysis

The FMF gap analysis for the 2020 Moderate Demand and 2020 Low Demand cases, shown in Figures 3.4-4 and 3.4-5, are nearly identical and similar in shape to the 2020 High Demand case. The benefit of the 42 kW gap filler for 50%-65% utilization is somewhat reduced. Overall, gap fillers of 5 to 6 kW and 150 kW are the most promising.

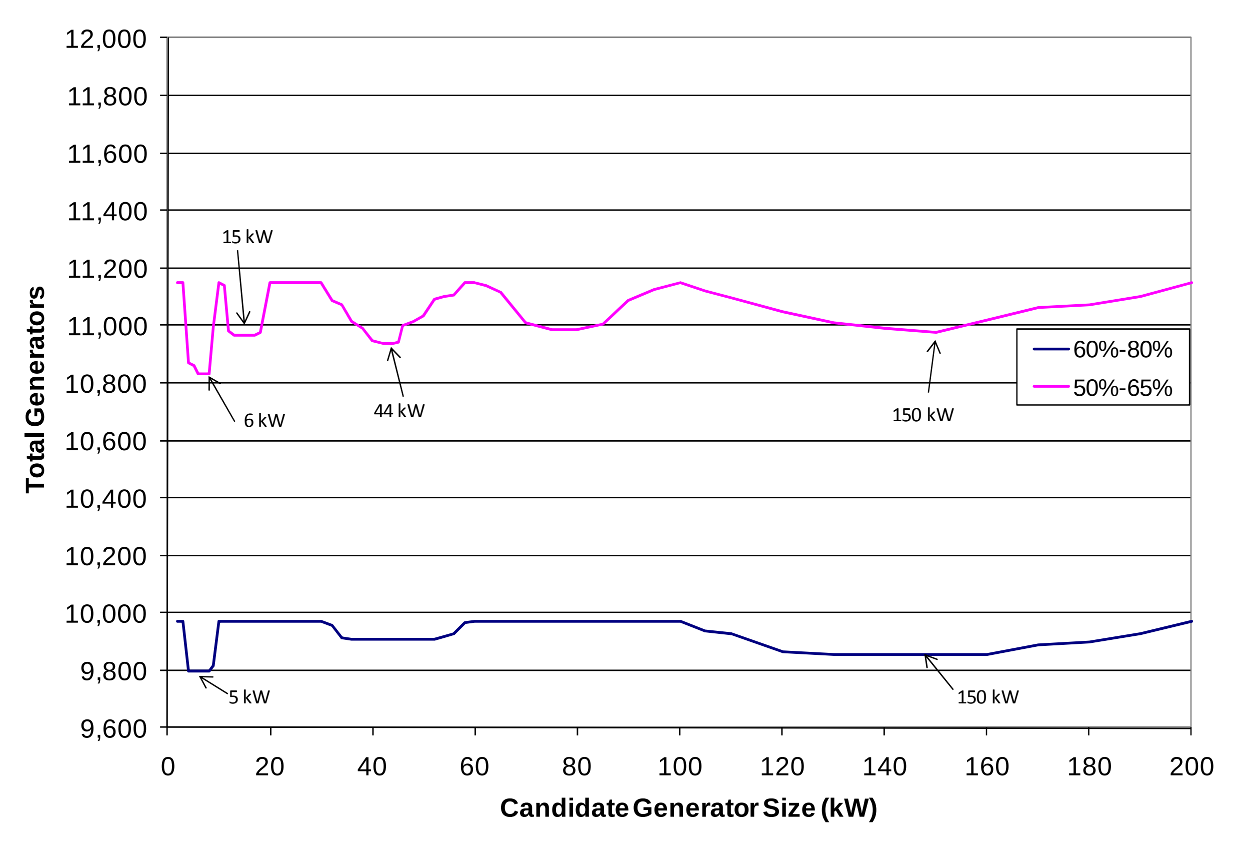

Figure 3.4-4. 2020 Moderate Demand FMF Gap Analysis

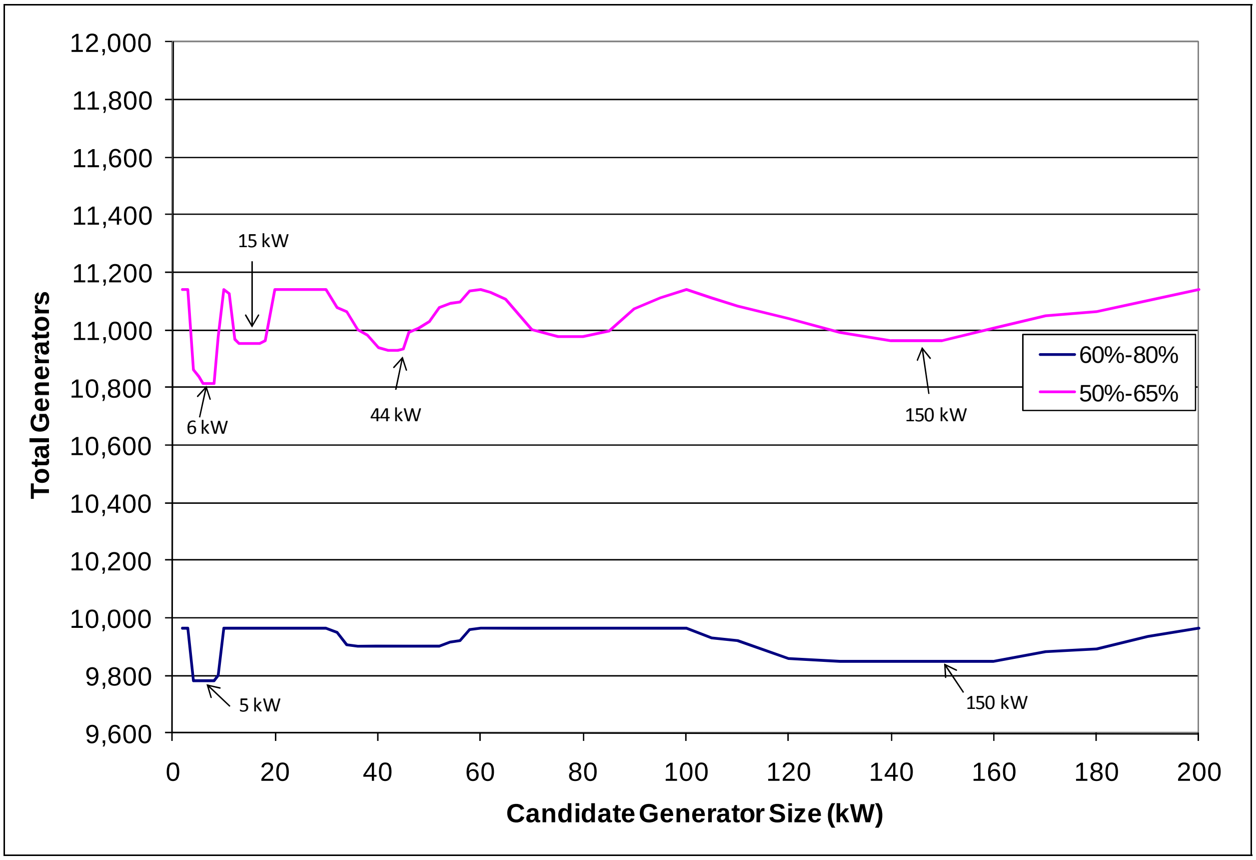

Figure 3.4-5. 2020 Low Demand FMF Gap Analysis

3.4.3. Modified Cases

The gap analysis for the modified cases shows approximately the same benefits to the candidate gap fillers. Figures 3.4-6 and 3.4-7, showing the FMF gap analysis for the 2012 Planning Factor Loads and 2020 Loads cases respectively, exhibit curves with virtually the same shape as the earlier cases. Gap fillers of 5 to 7 kW and 140 to 150 kW show benefits in all cases examined.

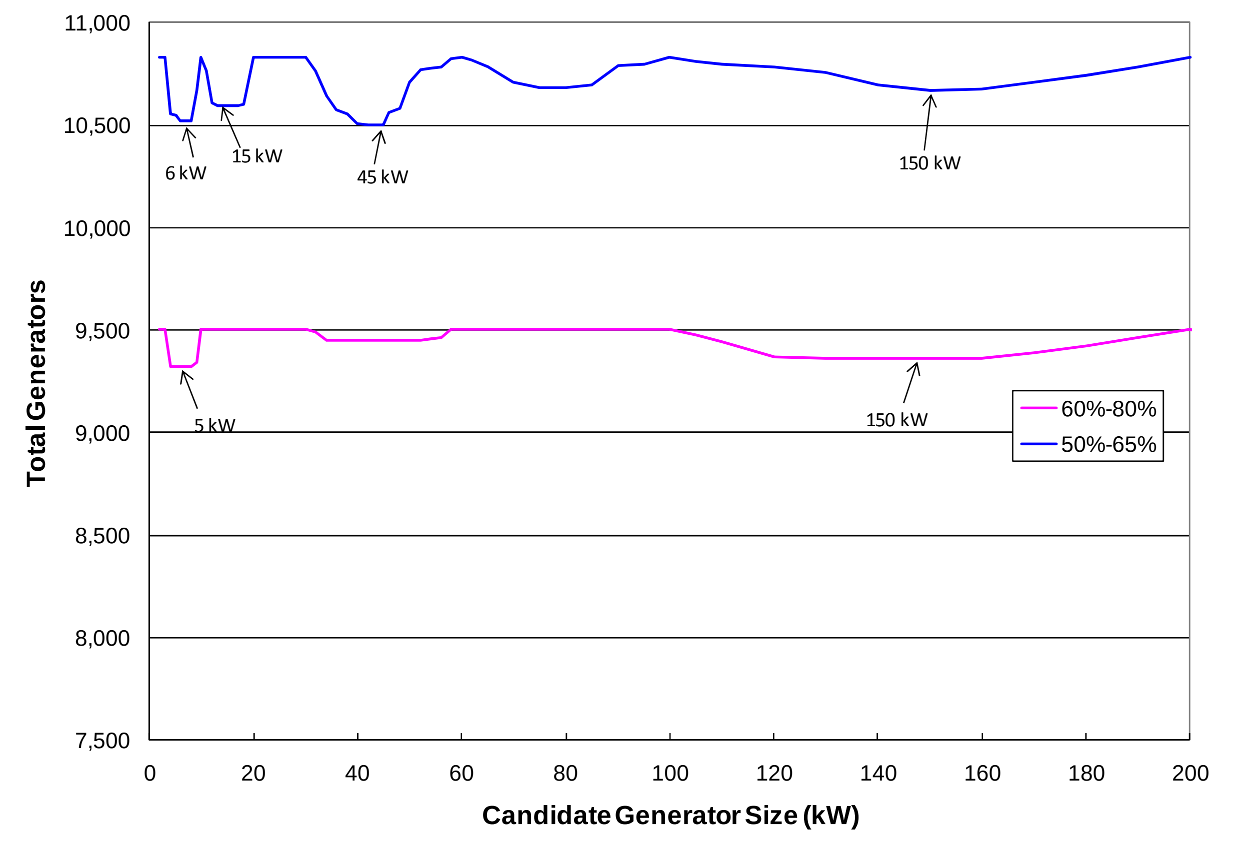

Figure 3.4-6 2012 Planning Factor Loads FMF Gap Analysis

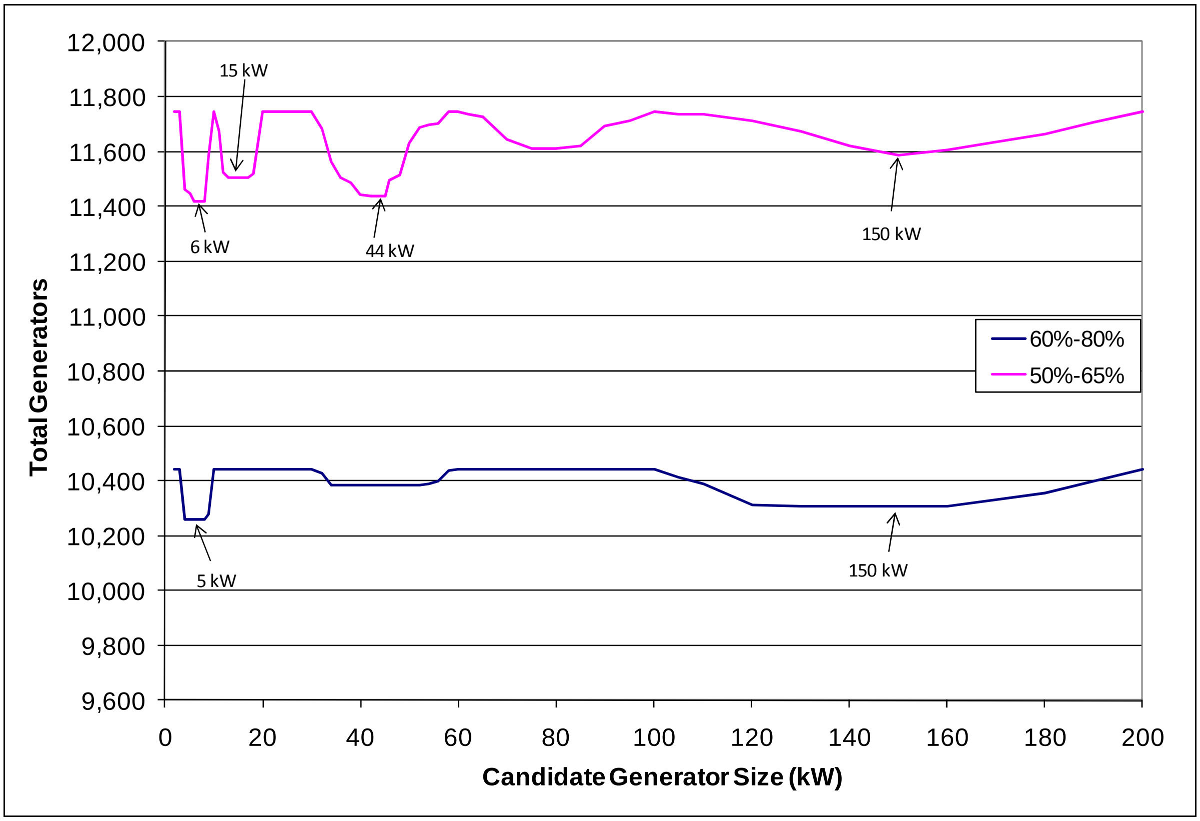

Figure 3.4-7 2020 Loads FMF Gap Analysis

3.5. ECU Requirements

As part of the shortfall analysis in Section 3.3, the Study Team included ECUs as loads. The number of each type of ECUs for the 2012 Documented Loads, by MEF, is shown in Table 3.5-1. These ECUs are those listed as the TFSMS AAO as of 5 June 2009.

Table 3.5-1 2012 Documented Loads ECU Requirements by MEF

TAMCN	Name	BTU/hr cool	Component	MARFORRES	I MEF	II MEF	III MEF	Total
B00017B	Air Conditioner, MCS, Horizontal, 60 HZ, 9000 Btu	9000	No	0	104	104	95	303
B00027B	Air Conditioner, MCS, Horizontal, 60 HZ, 18,000 Btu	18000	No	64	115	109	38	326
B00037B	Air Conditioner, Horizontal, 1.5T, 60 HZ, 18,000 Btu	18000	No	109	153	151	90	503
B00047B	ENVIRONMENTAL CONTROL UNIT, HZ1, 400FREQ, 18K BTU/hr	18000	No	6	5	5	5	21
B00057B	Air Conditioner, MCS, Vertical, 60 HZ, 3T	36000	No	0	0	3	0	3
B00067B	Air Conditioner, MCS Vertical, 400 Hz, 36,000 Btu	36000	No	30	28	28	18	104

TAMCN	Name	BTU/hr cool	Component	MARFORRES	I MEF	II MEF	III MEF	Total
B00087B	Air Conditioner, 5T, 60 HZ	60000	No	99	170	167	127	563
B00107B	Air Conditioner	120000	No	15	12	26	6	59
B00127B	Air Conditioner, MCS, Skid-Mounted	18000	No	194	66	69	52	381
B00147B	Air Conditioner, 3T, 36,000 Btu	36000	No	536	744	710	525	2,515
B00187B	Integrate Trailer-ECU-Generator (ITEG)	120000	No	49	9	11	4	73
B00747B	AIR CONDITIONER, MCS HORIZONTAL, 60HZ, 9K BTU/hr	9000	No	46	47	47	37	177
B00087B	Air Conditioner, 5T, 60 HZ	60000	Yes	23	32	32	24	111
B00127B	Air Conditioner, MCS, Skid-Mounted	18000	Yes	12	14	14	14	54
B00147B	Air Conditioner, 3T, 36,000 Btu	36000	Yes	4	23	23	7	57
B00187B	Integrate Trailer-ECU-Generator (ITEG)	120000	Yes	65	104	103	76	348
B00747B	AIR CONDITIONER, MCS HORIZONTAL, 60HZ, 9K BTU/hr	9000	Yes	1	9	9	7	26
Total							1253	1635

2012 Estimated Loads ECU requirements are based on component ECUs and ECUs associated with the various tent/shelters. The MEF totals are shown in Table 3.5-2. The most recent variant for each unit size was assumed.

Table 3.5-2 2012 Estimated Loads ECU Requirements by MEF

TAMCN	Name	BTU/hr cool	Component	MARFORRES	I MEF	II MEF	III MEF	Total
B00037B	Air Conditioner, Horizontal, 1.5T, 60 HZ	18000	No	227	486	495	347	1,555
B00047B	ENVIRONMENTAL CONTROL UNIT, HZ1, 400FREQ	18000	No	7	10	10	10	37
B00067B	Air Conditioner, MCS Vertical, 400 Hz	36000	No	12	12	12	6	42
B00087B	Air Conditioner, 5T, 60 HZ	60000	No	731	2107	2127	892	5,857
B00107B	Air Conditioner, 3T	36000	No	2155	2969	3096	1795	10,015
B00147B	AIR CONDITIONER, MCS HORIZONTAL, 60HZ	9000	No	103	923	986	598	2,610
B00747B	Air Conditioner, 5T, 60 HZ	60000	Yes	23	59	54	37	173
B00087B	Air Conditioner, MCS, Skid-Mounted	18000	Yes	23	32	32	24	111
B00127B	Air Conditioner, 3T	36000	Yes	12	14	14	14	54

TAMCN	Name	BTU/hr cool	Component	MARFORRES	I MEF	II MEF	III MEF	Total
B00147B	Integrate Trailer-ECU-Generator (ITEG)	120000	Yes	4	23	23	7	57
B00187B	AIR CONDITIONER, MCS HORIZONTAL, 60HZ	9000	Yes	65	104	103	76	348
B00747B	AIR CONDITIONER, MCS HORIZONTAL, 60HZ, 9K BTU/hr	9000	Yes	1	9	9	7	26
Total				3363	6748	6961	3813	20,885

The 2020 High, Moderate, and Low cases all have the same ECU requirement. The totals are given in Table 3.5-3.

Table 3.5-3 2020 ECU Requirements by MEF

TAMCN	Name	BTU/hr cool	Component	MARFORRES	I MEF	II MEF	III MEF	Total
B00037B	Air Conditioner, Horizontal, 1.5T, 60 HZ, 18,000 Btu	18000	No	225	488	495	347	1,555
B00047B	ENVIRONMENTAL CONTROL UNIT, HZ1, 400FREQ, 18K BTU/hr	18000	No	2	0	0	0	2
B00067B	Air Conditioner, MCS Vertical, 400 Hz, 36,000 Btu	36000	No	12	12	12	12	48
B00087B	Air Conditioner, 5T, 60 HZ	60000	No	731	2030	2128	833	5,722
B00107B	Air Conditioner	120000	No	2155	2930	3096	1770	9,951
B00147B	Air Conditioner, 3T, 36,000 Btu	36000	No	103	925	987	598	2,613
B00747B	AIR CONDITIONER, MCS HORIZONTAL, 60HZ, 9K BTU/hr	9000	No	23	60	54	35	172
B00087B	Air Conditioner, 5T, 60 HZ	60000	Yes	23	32	32	24	111
B00127B	Air Conditioner, MCS, Skid-Mounted	18000	Yes	12	16	16	14	58
B00147B	Air Conditioner, 3T, 36,000 Btu	36000	Yes	4	23	23	7	57
B00187B	Integrate Trailer-ECU-Generator (ITEG)	120000	Yes	65	104	103	76	348
B00747B	AIR CONDITIONER, MCS HORIZONTAL, 60HZ, 9K BTU/hr	9000	Yes	1	15	15	12	43
Total				3355	6620	6946	3716	20,637

These requirements are summarized in Figure 3.5-1. Another view of these requirements, combining all ECUs of the same size, is shown in Figure 3.5-2. (The 2012 Documented numbers are the TFSMS AAO quantities.) The large shortfall in 60k BTU/hr units is caused by the Modular Command Post System. The shortfall in 120k BTU/hr units is caused by the Modular GP Tent System.

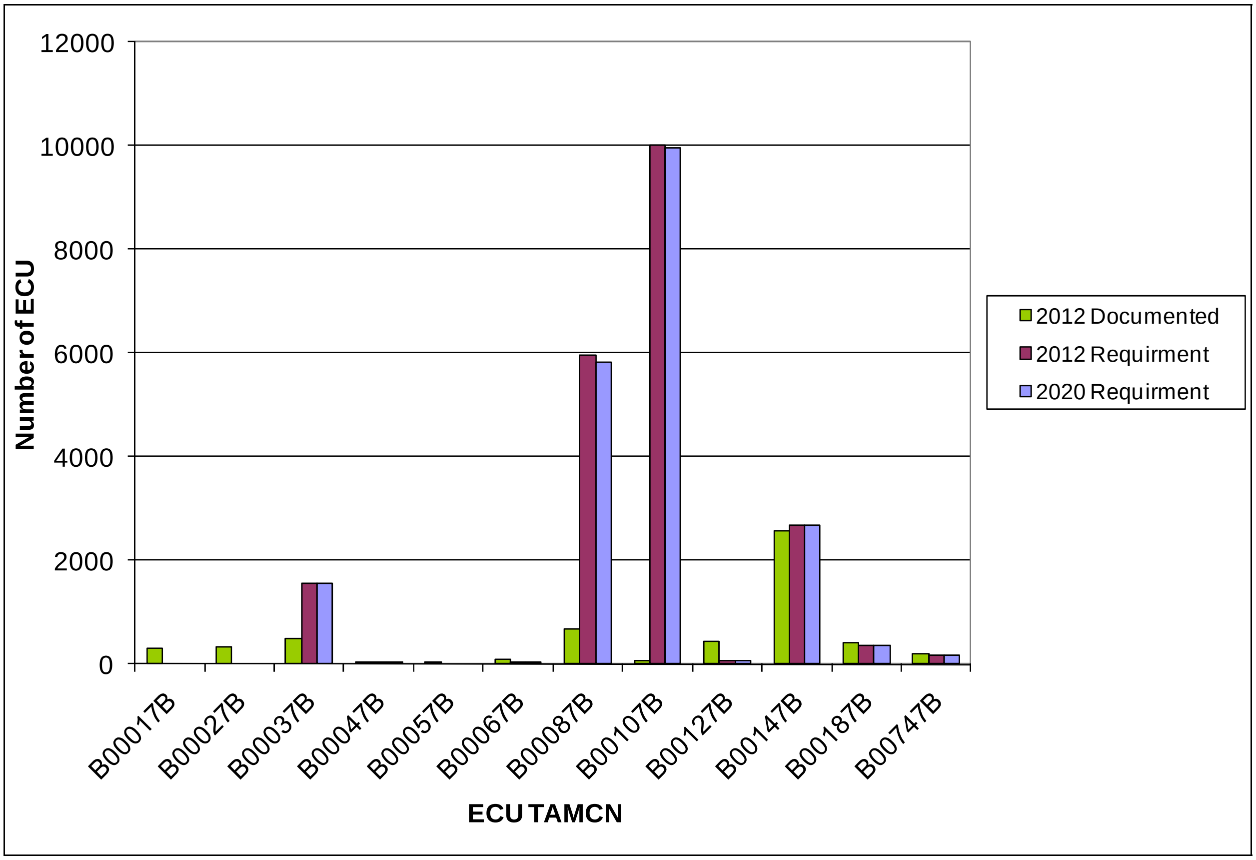

Figure 3.5-1. FMF ECU Requirements by TAMCN

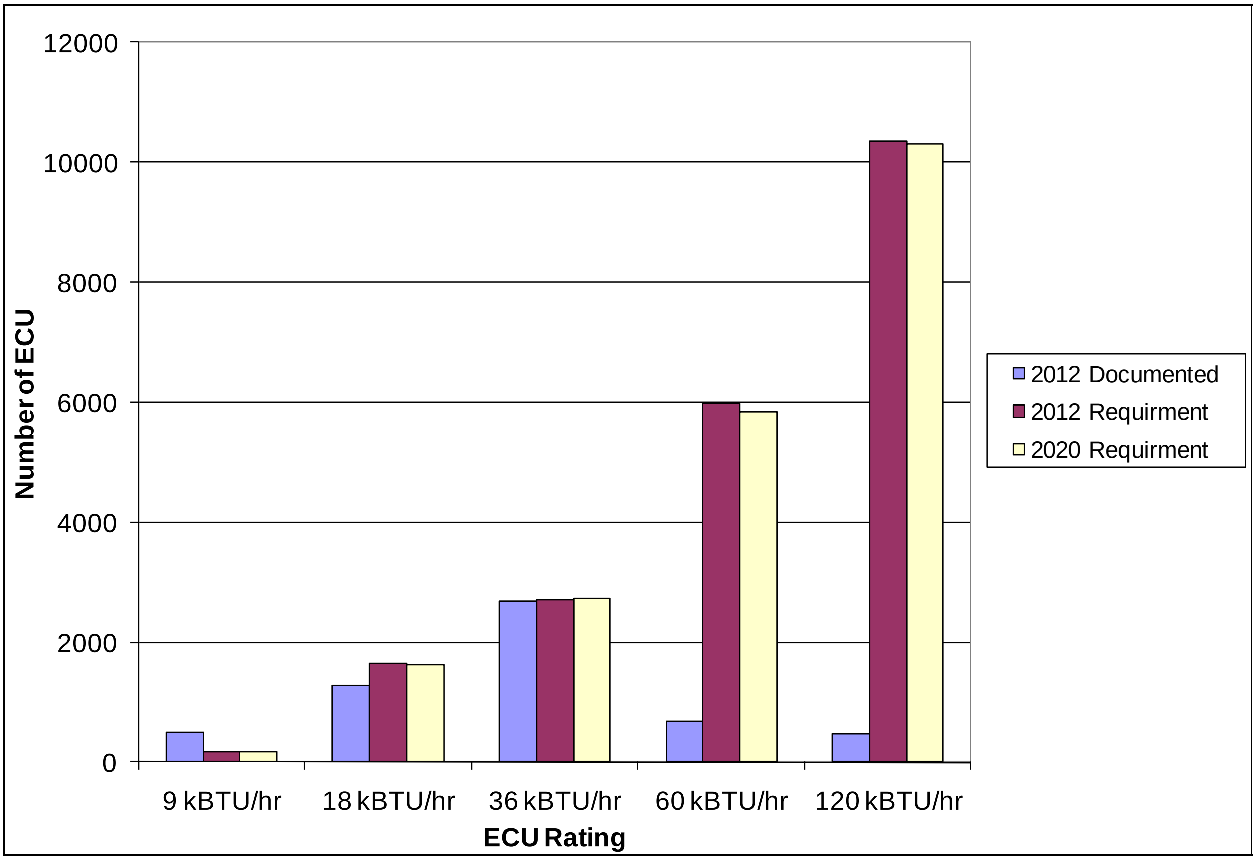

Figure 3.5-2. FMF ECU Requirements by Size

4. ENVIRONMENTAL AND OTHER CONSIDERATIONS

ECUs are subject to strict and evolving regulations in the US and Europe regarding the working fluid, or refrigerant, used in the system. All current ECUs in the Marine Corps use the R-22 refrigerant, which must be replaced in the coming years. The evolution of refrigerant regulations and their implications are discussed below.

4.1. Background

Chlorofluorocarbons (CFC) were developed in the 1930s and were designed to be non-toxic, non-flammable, and non-reactive chemicals. The inert properties of CFC made them more attractive for use as refrigerants than the natural refrigerants, ammonia and sulfur dioxide, which are toxic substances. In the 1980s it was discovered that CFCs were a major contributor to the depletion of the ozone layer[14]. Hydrochlorofluorocarbons (HCFC) were created to replace CFCs which were being rapidly phased-out due to their effects on the environment. HCFCs have one twentieth the ozone depleting potential as CFCs. The HCFCs R-12 and R-22 are very widely used in air conditioning and refrigeration applications. HCFCs still have a significant impact on the environment and are being phased out by 2030 as dictated by the Montreal Protocol. The Montreal Protocol is an international treaty designed to address ozone layer depletion by setting up a timetable for the total elimination of several substances including CFCs, HCFCs, and Halons. Hydrofluorocarbons are being developed for use in refrigerant applications while having no ozone depleting potential.

4.2. R-22 Phase-out Timelines

4.2.1. US Phase-out Regulations

The United States is on schedule to meet Montreal Protocol requirements. The United States' phase out schedule for all HCFCs including R-22 is given in the Table 4.2-1.

Table 4.2-1: U.S. R-22 Phase-out Schedule[15]

Year	% Reduction in Production and Consumption	Implementation of HCFC Phase-out
2004	35.0	No production or importation of HCFC-141b.
2010	75.0	No production or importation of HCFC-141b or HCFC-22, except for use in equipment manufactured before 1-1-2010.[16]
2015	90.0	No production or importation of any HCFCs, except for use as refrigerants in equipment manufactured before 1-1-2020.
2020	99.5	No production or importation of HCFC-141b and HCFC-22.[17]
2030	100	No production or importation of any HCFCs.

[14] Stratospheric ozone filters out ultraviolet radiation and helps prevent skin cancers. In the stratosphere, incident solar radiation can cleave the chlorine atom off of the CFC. The chlorine molecule will act as a catalyst in transforming ozone molecules into oxygen atoms and can transform several thousand ozone molecules in its lifetime.

[15] U.S. Environmental Protection Agency, "HCFC Phase-out Schedule" 20 Aug 2008. http://www.epa.gov/ozone/title6/phaseout/hcfc.html.

[16] New equipment can be manufactured to use R-22 as long as the R-22 used is recycled. R-22 can be produced to service old equipment.

[17] R-22 may no longer be produced to service old equipment. Only recycled R-22 may be used to service old equipment

4.2.2. EU Phase-out Regulations

The European Union is ahead of the United States in phasing out R-22. The European Union's phase-out schedule is given in the Table 4.2-2[18].

Table 4.2-2 European R-22 Phase-out Schedule

Year	% Reduction in Production and Consumption [3]	Implementation of HCFC Phase-out
2001	0	No production or importing of HCFCs for use in equipment manufactured after 1-1-2001.
2010	65	No production or importation of HCFCs to service existing equipment.
2015	90	No production or importation of any HCFCs.

There are two approaches to accommodating the retirement of R-22, replace the entire ECU with a system designed for an allowed refrigerant or "retrofit" existing ECUs with a newer refrigerant. Long term, new systems designed for then available refrigerants will no doubt be more efficient. However, during a transition period, retrofit might be more cost effective. The retrofit option must consider both cooling performance and equipment lubrication (R-22 contains mineral oil and changing lubricant can be more costly).

4.3. Retrofit Options

4.3.1. R-22 Replacement Candidates

The prime long term candidate for replacing R-22 is R-410A. Old systems cannot be retrofitted to use R-410A due to the significantly higher operating pressures required for a system using R-410A. Other candidates exist for use in the interim between retiring old systems and acquiring new R-410A systems. R-404A, R-507, R-417A, and R-407C are prime candidates for retrofit of existing R-22 ECUs. These refrigerants are contrasted below based on their coefficient of performance and cooling capacity. The coefficient of performance (CoP) of a refrigerant is defined as the cooling capacity divided by the power consumption.

4.3.1.1. R-417A

R-417A is an inexpensive refrigerant to replace R-22, because R-417A can be used in existing R-22 hardware and does not require a different lubricant. R-417A has a critical temperature of 194 degrees Fahrenheit versus R-22's critical temperature of 205 degrees Fahrenheit. Critical temperature is the highest temperature at which a refrigerant can be condensed to a liquid regardless of pressure. If the condensing temperature approaches the critical temperature a significant loss of efficiency for the refrigeration cycle results. R-417A has a similar efficiency to R-22 although it has less cooling capacity. Cooling capacity determines the power requirements for an air conditioner. A refrigerant with less capacity will require more power to produce the same amount of heat transfer as a refrigerant with greater capacity. While R-417A is an

[18] DETR/DTI, "Refrigeration and Air Conditioning CFC and HCFC Phase Out" Dec 2000. http://www.berr.gov.uk/files/file29101.pdf.

easy refrigerant to retrofit because it uses the same lubricant, it is outperformed by refrigerants that use Polyol Ester (POE) Oils for lubricants. The efficiency of R-417A is approximately 85% of the efficiency of R-22 for a wide range of evaporator temperatures. The cooling capacity of R-417A is about 80% of the cooling capacity of R-22 at an evaporator temperature of 45 degrees Fahrenheit. The cooling capacity decreases with decreasing evaporator temperature to only 75% at an evaporator temperature of -40 degrees Fahrenheit[19]. [4]

4.3.1.2. R-407C

R-407C requires a more expensive retrofit than that required by R-417A. R-407C requires an existing air conditioner's lubricant to be replaced by POE oil. This requires flushing the lubrication system multiple times with the POE oil to assure there is no contamination of the new oil by the old oil. R-407C has a critical temperature of 187 degrees Fahrenheit and a temperature glide. The temperature glide is the difference between the temperature at which the refrigerant first begins to condense and the temperature at which all the refrigerant has been condensed to liquid. Temperature glide isn't an issue in small air conditioning applications but may be a problem in some chillers. R-407C's efficiency is almost identical to R-22's which starts to decrease slightly for evaporator temperatures cooler than 20 degrees Fahrenheit. The cooling capacity of R-407C is greater than R-22 for evaporator temperatures above 20 degrees Fahrenheit and worse than R-22 for evaporator temperatures below 20 degrees Fahrenheit[20].

4.3.1.3. R-404A

As with R-407C, R-404A also requires use of POE oil as lubricant. R-404A has a critical temperature of 162 degrees Fahrenheit. R-404A performs better than R-22 at lower evaporator temperatures and performs worse than R-22 at high evaporator temperatures. R-404A has a small temperature glide. The efficiency of R-404A is significantly better than R-22 for evaporator temperatures lower than 10 degrees Fahrenheit and significantly worse than R-22 for temperatures greater than 10 degrees Fahrenheit. The cooling capacity of R-404A is significantly better than R-22 for evaporator temperatures lower than 30 degrees Fahrenheit and significantly worse than R-22 for evaporator temperatures greater than 20 degrees Fahrenheit. R-404A's efficiency and cooling capacity change rapidly with changing evaporator temperature[21].

4.3.1.4. R-507

R-507 is very similar to R-404A and requires use of POE oil as lubricant. R-507 has a critical temperature of 159 degrees Fahrenheit. Like R-404A, R-507 also performs better than R-22 at lower evaporator temperatures and worse than R-22 at higher evaporator temperatures. R-507 has a much smaller temperature glide than R-404A. R-507 is about 1% less efficient than R-404A at an evaporator temperature of 32 degrees

[19] DuPont, "Selection Guide for Retrofitting R-22 Equipment," http://www.lydallaffinity.com/sales-support/refrigerants/RetrofitR22.pdf.
[20] Ibid.
[21] Ibid.

Fahrenheit; however R507 has about a 1.5% greater cooling capacity than R-404A at the same evaporator temperature. R-507 comes out slightly ahead of R-404A[22].

4.3.2. Global Warming Potential

Most of these refrigerants are greenhouse gasses. The impact of refrigerants on global warming was not a consideration in setting the current regulations, but is likely to become important in the future. The climate effects of various gasses are measured on a global warming potential (GWP) scale where carbon dioxide is unity. The GWP of R-22 and its possible replacements are given in Table 4.3-1.

Table 4.3-1 Global warming potential of candidate retrofit refrigerants

Refrigerant	GWP
R-22	1500-1810
R-407C	1520-1780
R-417A	1950-2140
R-404A	3260-3780
R-507	3300-3900

4.3.3. Implications

R-417A can be inexpensively retrofitted in existing ECUs, but will require derating the ECUs by up to 20%. The derating of ECUs can be compensated by increasing ECU size (e.g. replace an R-22 B0005 by an R-417A B0011) at the cost of increased power consumption. Retrofitting ECUs with R-407C would provide almost identical performance to R-22 but would require a more involved retrofitting process and the purchase of POE oil. Retrofitting to R-407C likely would require sending the ECUs to an intermediate maintenance shop or the depot and increase logistical burden. An R-507 retrofit would require usage of the same oil as R-407C and would present the same challenges, but it will outperform R-22 at low evaporator temperatures. However, possible future green house gas regulations could affect R-507 availability.

4.4. New Equipment Options

New equipment designs can be adapted to the refrigerant, allowing a wider set of refrigerant choices. Natural refrigerants, carbon dioxide (CO_2 or R-744) and hydrocarbons, such as propane (R-290), are notable for having very low GWP, shown in Table 4.4-1. Ammonia (R-717) also has potentially high performance, especially for low temperature applications. Each of these options has drawbacks. Hydrocarbons are flammable. Hydrocarbons and ammonia are toxic. Ammonia, in the presence of water, will corrode copper. CO_2 requires very high pressure for efficient operation and performs poorly at high ambient temperatures. Although none of these problems are insurmountable, the cost of engineering around them (for example, adding secondary cooling loops to isolate the flammable and/or toxic refrigerant from the air flow to the conditioned space) has prevented their widespread use in applications such as portable ECUs.

[22] York-Marine, “Paper - Retrofit” http://www.york-marine.com/uploads/media/Paper__Retrofit_030218.pdf.

Table 4.4-1 Characteristics of New-System Refrigerants

Refrigerant	GWP	Comment
R-410A	1739	Current residential standard
R-744 (CO2)	1	High pressure; reduced performance at high ambient temperature
R-290 (Propane)	11	Flammable
R-717 (Ammonia)	0	Toxic

It is still possible that climate regulations will require very low GWP refrigerants. To gage the likelihood of such a requirement, it is useful to estimate the Life Cycle Climate Potential (LCCP) for various refrigerants. The LCCP is an estimate of the total CO_2-equivalent impact of an ECU over its expected life. There are three components: the GWP of the refrigerant, including annual leakage; the climate impact of manufacturing the ECU; and the CO_2 produced in providing energy to the unit. The Study Team used a hypothetical 36k BTU/hr ECU powered by a MEP805B 30 kW generator for comparison. The generator is reported to consume 2.6 gal/hr at the rated load. Refrigerant leakage was found for a limited number of systems; lifetime leakage is reported to be between 0.6 and 1.26 kg.[23] The Study Team has no data on the manufacturing impact for hypothetical future designs, so this factor is omitted in the calculations depicted in Figure 4.4-1. However, the safety and high pressure requirements of the natural refrigerants probably mean that they have larger manufacturing impacts than many other options. The horizontal axis is the Seasonal Energy Efficiency Ratio[24] (SEER) of the hypothetical design. As a point of reference, the current standard SEER for residential air conditioning units is 13. Note that a SEER increase of 0.5 to 1.5 in this example calculation negates the natural refrigerants' low GWP advantage.

[23] http://www.arap.org/adlittle/6.html#3 , accessed 28 June 2009.

[24] SEER is in units of BTU/watt-hr. A laboratory test would directly measure the coefficient of performance (COP) which is the ratio of heat transferred to the energy used (dimensionless). The COP depends on operating conditions. The SEER, other than a change in units, is the average COP over a "typical" cooling season. SEER depends on climate, but is a more useful characteristic when attempting to calculate lifetime energy consumption.

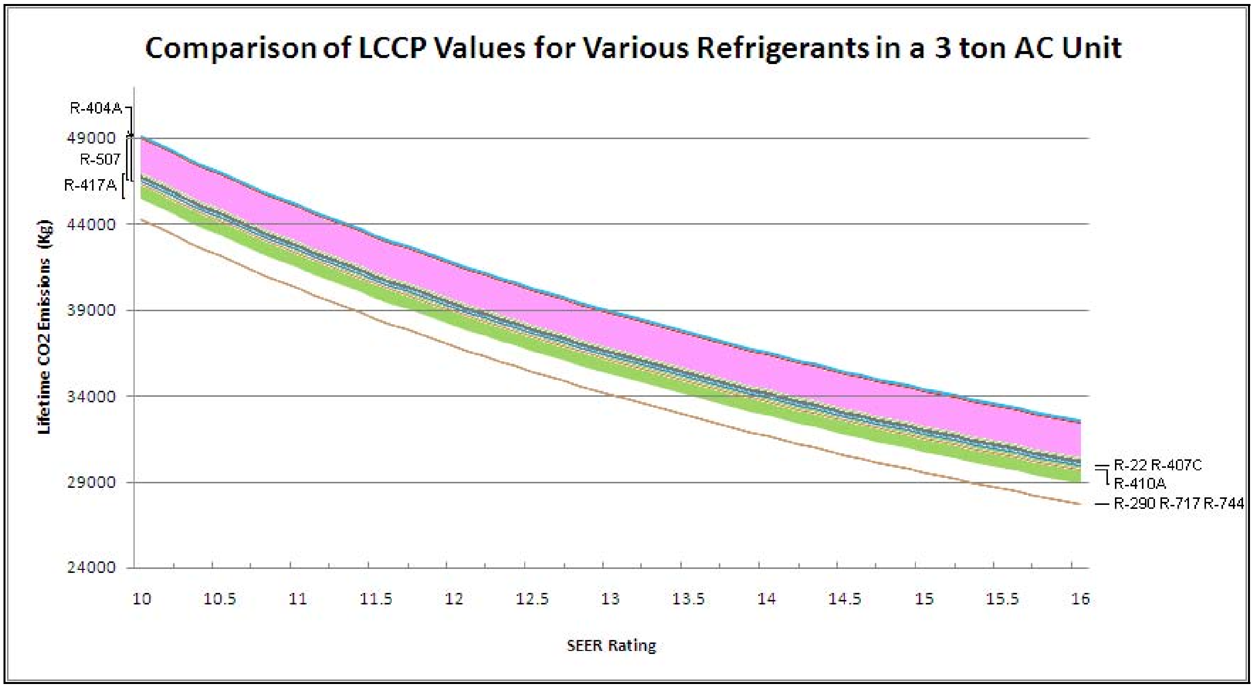

Figure 4.4-1. Comparison of LCCP for Various Refrigerants

5. OBSERVATIONS AND CONCLUSION

The Study Team reviewed all end items in the Marine Corps for MEP and ECU requirements. Documentation was incomplete for 279 TAMCNs. By using planning factors from field manuals and training materials and researching similar civilian systems, the team was able to estimate loads for nearly all items. The MEP requirements were categorized by class (critical, required, or important) and distribution architecture (dedicated, exclusive, or grid). The Study Team tabulated loads at the company level by category and assigned generators according to a set of rules approved by the Study Sponsor.

Depending upon the rules regarding how close to their rated power that generators are loaded, the analysis, using standard planning factors and including ECU in critical loads, showed a 2012 Planning factor Loads shortfall of 677 (60% to 80%) to 1998 (50% to 65%) generators, compared to the June 2009 AAO, and approximately 15,000 ECUs. The shortfall includes approximately 2300 to 2800 200 kW generators partially offset by an excess of some of the smaller generators. These results are driven by the assumption that each tent and shelter will be supplied with an ECU as is the practice in current deployments. The Marine Corps may or may not adopt this practice as permanent doctrine. In the 2020 Loads case, the shortfall grows to 1610 (60% to 80%) to 2916 (50% to 65%) generators.

When utilizing generators at 60% to 80%, acquiring 5 to 6 kW generators could save approximately 180 generators in 2012 and 2020. At 50% to 65% utilization, 150 kW generators could save approximately 140 generators in both time frames. Given the large number of GP tents requiring 120 kBTU/hr ECUs, an improved tent and companion 96 kBTU/hr ECUs could also have a significant impact.

If the Marine Corps retains currently deployed ECUs as war reserve, the R-22 refrigerant currently used must be replaced (by 2015 to comply with European regulation). Several options exist, but the systems should be tested using the retrofit refrigerant to verify their performance.

Phase 2 of the Study will examine tactical deployments. A tactical distribution of equipment, instead of the TO/E based load centers examined herein, may produce different shortfalls. If adequate fuel consumption data becomes available, the Study Team will be able to estimate fuel consumption based on generator choices in Phase II.

APPENDIX A: ACRONYMS

AAO....Approved Acquisition Objective
AC....Alternating Current
ACE....Air Combat Element
BCOC....Basic Communications Officer Course
BTU....British Thermal Unit
CFC....Chlorofluorocarbons
COC....Combat Operations Center
COP....Coefficient of Performance
CPS....Collective Protection System
DC....Direct Current
ECU....Environmental Control Unit
EPS....Expeditionary Power Systems
FMF....Fleet Marine Force
FP....Fielding Plan
FYDP....Future Years Defense Plan
GFI....Government Furnished Information
GWP....Global Warming Potential
HCFC....Hydrochlorofluorocarbons
ID....Item Designator
ITEG....Integrated Tent ECU Generator
JLTV....Joint Light Tactical Vehicle
LCCP....Life Cycle Climate Performance
MAGTF....Marine Air-Ground Task Force
MARCORSYSCOM....Marine Corps Systems Command
MARFORRES....Marine Forces Reserve
MCLB....Marine Corps Logistics Base
MEB....Marine Expeditionary Brigade
MEF....Marine Expeditionary Force
MEP....Mobile Electric Power
MEPDB....Mobile Electric Power Database
MEU....Marine Expeditionary Unit
MCPS....Modular Command Post System
MGPTS....Modular General Purpose Tent System
OEF....Operation Enduring Freedom
OIF....Operation Iraqi Freedom
PEI....Principal End Item
PM....Program Manager
POE....Polyolester
POR....Program of Record
SEER....Seasonal Energy Efficiency Ratio

SME ....Subject Matter Expert
SOA...Sustained Operations Ashore
TAMCN .... Table of Authorized Materiel Control Number
TBP ....To Be Published
TFSMS ....Total Force Structure Management System
TM .... Technical Manual
TMDE ....Test, Measurement, and Diagnostic Equipment
TO/E...Table of Organization and Equipment
TOPIC ....The Online Project Information Center
TQG .... Tactical Quiet Generator
ULSS.. User’s Logistics Support Summary
UURI ....Using Unit Responsibility Item
VAC.. Volts AC

APPENDIX B: BIBLIOGRAPHY

Hundreds of official source documents were reviewed in the search for load data. Those documents are listed as sources in Appendix C. Other reference material is listed here.

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68. York-Marine, *Paper – Retrofit*, http://www.york-marine.com/uploads/media/Paper__Retrofit_030218.pdf.

APPENDIX C: MEP AND ECU LOAD INFORMATION

All MEP and ECU load information collected during Task 1 is provided in an electronic Excel file accompanying this report. The first tab in the file is a key to the color coding used in the second "Baseline Loads" sheet. The load estimations using analogous components are also included in this file in the "Power Estimation," and "Component Categories" sheets.

APPENDIX D: LOAD CENTERS

The Study Team generated a list of unit types, by unit type code, for which the documented power consumption was greater than 180 kW. It was assumed that those unit types would be the most likely to operate as multiple load centers. The Study Team reviewed each unit mission statement and AAO to assess whether the unit should be subdivided into multiple load centers. Of the 51 unit types assessed, it was determined that 14 would likely need to be subdivided into multiple load centers, and the Study Team developed a subdivision strategy for each of these 14 unit types. (For instance, the strategy for some headquarters units was "*Unit will operate in two parts, Main and FWD. Split communications gear and MCPS into 2/3 @ Main and 1/3 @ FWD*." The subdivision strategies were provided to the Study Sponsor for review and approval. The Study Team then retrieved the AAOs for the 47 individual units in these 14 unit types and applied the subdivision strategy to manually allocate the unit's equipment (except ECUs) across the appropriate number of load centers.

ECU equipment was subsequently assigned to the subdivided load centers using different approaches for supporting assessment of 2012 Documented Loads (2012 documented loads) and 2012 Estimated Loads (2012 estimated loads). For 2012 Documented Loads, where the TFSMS AAO of ECUs was used for assessing power requirements, the ECUs were subdivided among load centers based upon the previous subdivision of tent/shelters among load centers (e.g., if a UIC was broken into 2 load centers and one received ¾ of the tent/shelters, it would received ¾ of the ECUs in the AAO). Note that, for estimated loads, where the TFSMS AAO of ECUs was not used, ECUs were assigned to specific tent/shelters and equipment based upon documented BTU/hr requirements.

Special consideration was given to those units whose AAO did not include any tent/shelters at all. For 2012 Documented Loads, all ECUs were assigned to the primary (main) load center. In 2012 Estimated Loads, tent/shelter estimates were used in place of individual equipment items assigned to be used in tent/shelters. Therefore units with no tent/shelters appeared to have a greatly reduced power requirement. For these units, the 2012 Estimated Loads, estimated case, data was replaced with 2012 Documented Loads, documented data, in order to enable a more realistic MEF-level comparison of the two cases.

The complete list of UICs, TAMCNs, subdivided quantities and subdivision strategies are provided in the attached file, "Appendix_D_Load_Center_Subdivision.xls." The power requirements and generator assignments for each individual load center for each of the five analytical cases are provided in the attached file, "Appendix_D_ Load_Center_Power.xls."

APPENDIX E: EQUIPMENT ASSIGNED TO TENT/SHELTERS

As described in section 3.2.2, power requirements based on estimated loads used tent/shelter power requirements based on the BCOC planning factors in place of the power requirement of the individual equipment items used in those tent/shelters. The list of equipment items requiring power and whether they are used in tent/shelters is provided in the attached file “Appendix_E_Shelterized_Equipment.xls.”

APPENDIX F: PROGRAMS OF RECORD

The list of 61 POR likely to have an impact on future MEP requirements that were derived from the collection of 970 projects downloaded from TOPIC is provided in the attached file “Appendix_F_TOPIC_POR.xls.” Yellow tinted cells indicate systems for which official TAMCNs have not been issued. The Study Team assigned surrogate TAMCNs for these systems in order to be able to analyze them using procedures identical to those used on all other TAMCNs.

APPENDIX G: ACE REQUIREMENTS

ACE equipment is purchased with Navy funds, but will be maintained with Marine Corps funds. Table G-1 shows the total MEP and ECU requirement, including backup requirements, for the ACE, less mobile facilities, as provided by Headquarters Marine Corps (HQMC) ASL. More detail, including the associated end items requiring power, is given in an electronic file accompanying this report. Table G-2, also provided by ASL, gives requirements for the mobile facilities, self contained aviation maintenance, administration, and storage shelters.

Table G- 1 ACE MEP and ECU requirements

Item	TAMCN	NSN	Quantity
MEP-805B	B0953	6115-01-274-7389	127
MEP-803A	B0891	6115-01-275-5061	42
MEP-531A	B0980	6115-01-435-1565	61
ITEG	B0018	2330-01-556-9648	39
ECU, 3-ton	B0014	4120-01-526-2397	90
ECU, 1-1/2-ton	B0003	4120-01-526-1588	25

Table G- 2 Mobile Facility MEP and ECU Requirements

Item	TAMCN	NSN	Quantity
MEP-006A	obsolete	6115-00-118-1243	5
MEP-009A			125
MEP-105A		6615-00-118-1252	186
MEP-807A	B1045	6115-01-296-1463	57
MEP-809A	B0083	6115-01-296-1462	77
MMG-1A			186
ECU	various	various	6750

APPENDIX H: JLTV IMPACTS

The Study team reviewed systems with component HMMWVs and identified 17 TAMCNs as likely candidates for using exportable vehicle power. Fourteen of these TAMCNs have component generators. The other three TAMCNs are included in 37 load centers. The generator assignments for all these load centers in the 2020 High, Moderate, and Low cases, for 60% - 80% utilization, are provided in an accompanying Excel file titled “Appendix H - JLTV.xls.” The Study assumes that JLTV power utilization of 0% to 100% is acceptable. The Excel file contains multiple sheets:

- A set of sheets whose names include the suffix “component” analyze the 14 identified TAMCNs with component HMMWVs and component generators. These systems have the same MEP requirements in all three load cases.
    - The “Baseline-component” sheet lists the MEP requirements if the TAMCN retains the HMMWV(s) as prime mover.
    - The “30 exportable-component” sheet lists the MEP requirements if the TAMCN is upgraded to JLTV(s) with 30 kW of exportable power.
    - The “10 exportable-component” sheet lists the MEP requirements if the TAMCN is upgraded to JLTV(s) with 10 kW of exportable power.
- A set of three sheets for each load case analyzing the MEP requirements for zero, 10, and 30 kW of JLTV exportable power. These sheets are in a format similar to Appendix C.
- A “Summary” sheet listing the total number of generators of each size required in each load case/JLTV power combination.
- A number of chart sheets.